Environment Canada Environnement Canada

Canada

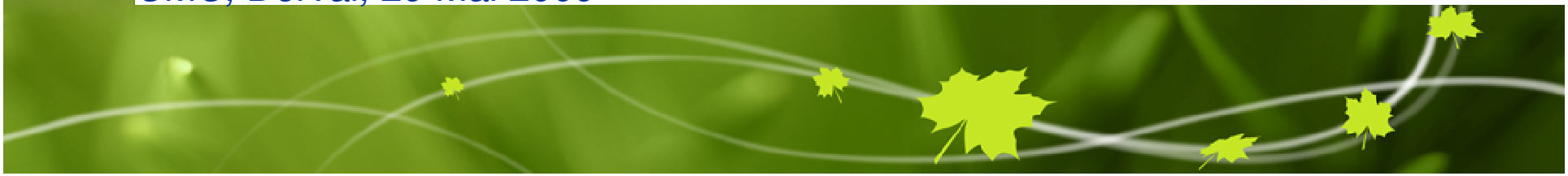
Impact study with observations assimilated over North America and the North Pacific Ocean at MSC

Stéphane Laroche and Réal Sarrazin

Environment Canada

Séminaire interne

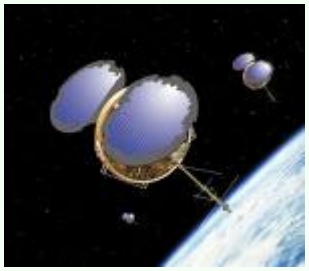
CMC, Dorval, 29 Mai 2009



Outline

- Overview of the MSC data assimilation systems
- Summary of contribution of the current observing networks reported in the last WMO workshop on the impact of various observing systems on NWP
- Presentation of the MSC Observing System Experiments made for the two-month period of January and February 2007

Meteorological observing systems used in the MSC global data assimilation systems



Micro satellites GPS-RO
(COSMIC (6), GRACE)

Polar-orbiting Satellites
(NOAA-15,16,17,18,METOP-A;
DMSP-F13; AQUA, TERRA; QuikSCAT)

Geostationary Satellites
(GOES-11,12, Meteosat-7,9; MTSAT-1R)

Aircraft
(BUFR, AIREP, AMDAR, ADS)

Upper-air sites
(TEMP, PILOT, DROP)

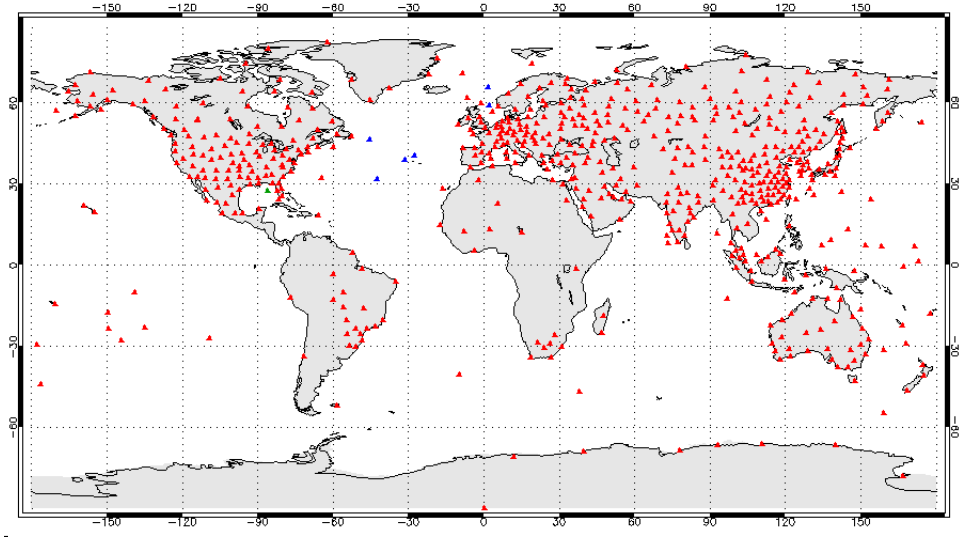
Wind profilers
(NOAA network)

Buoys and ships

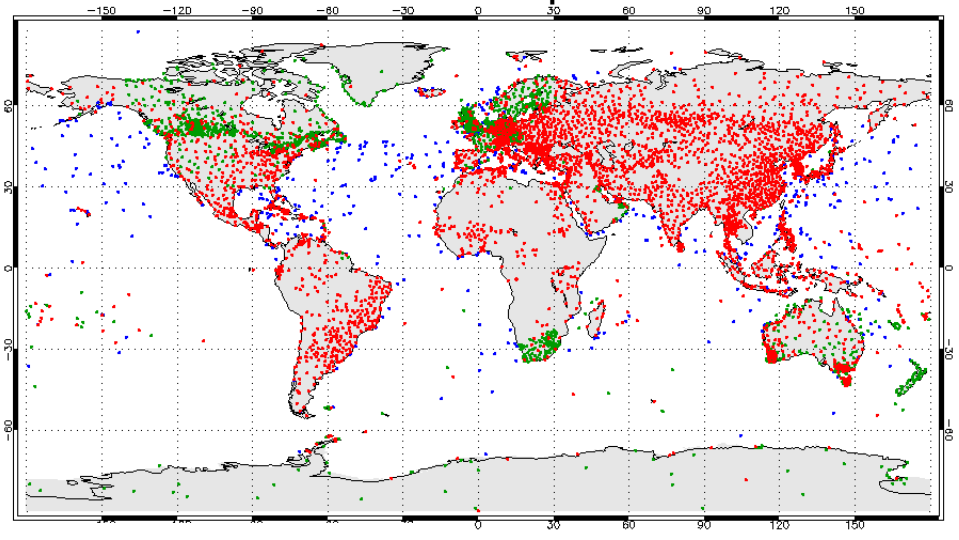
Surface stations
(SYNOP, ASYNOP,METAR)

Conventional observations

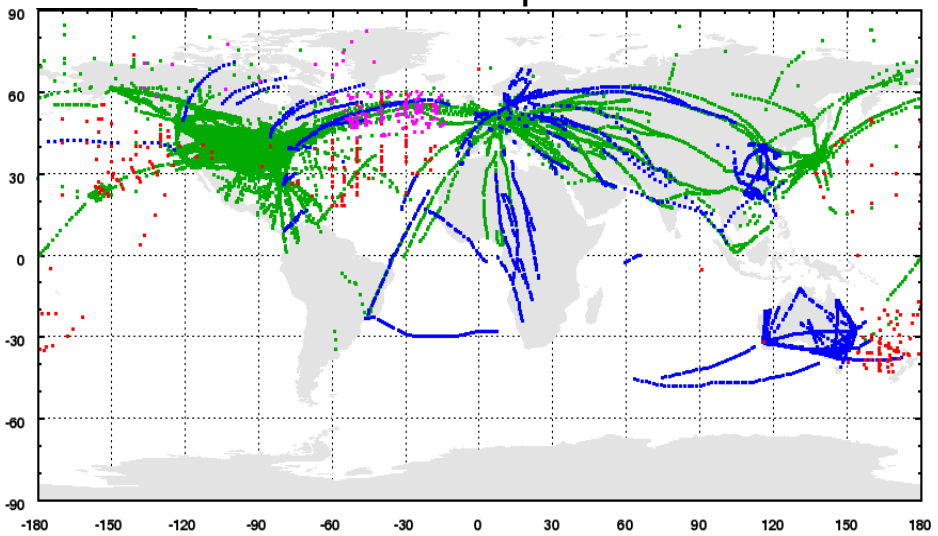
Radiosondes



Surface reports



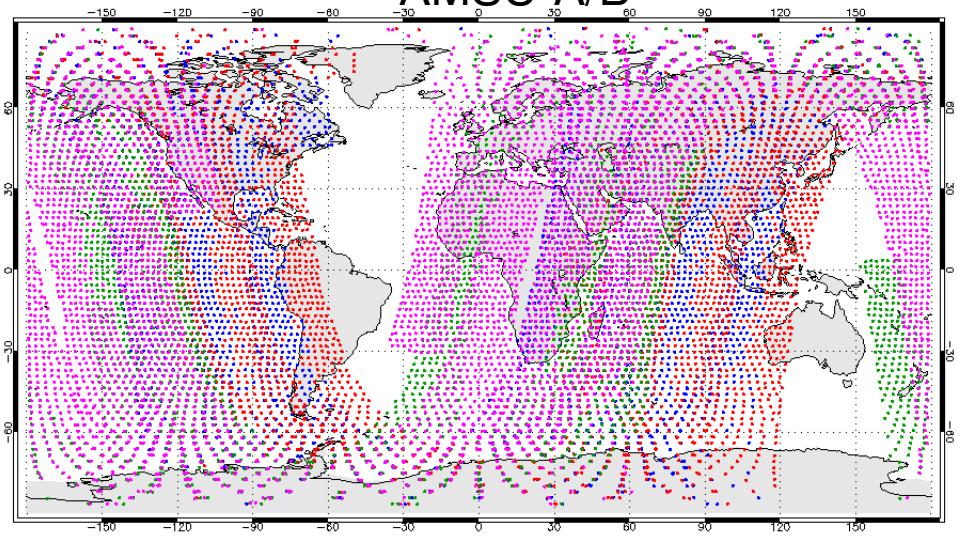
Aircraft reports



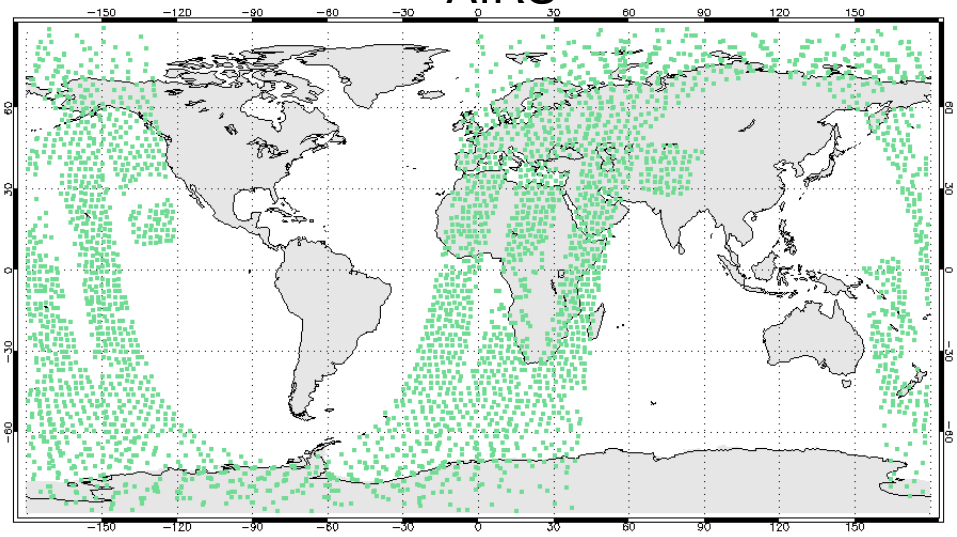
Passive remote sensing observations

(polar-orbiting satellites)

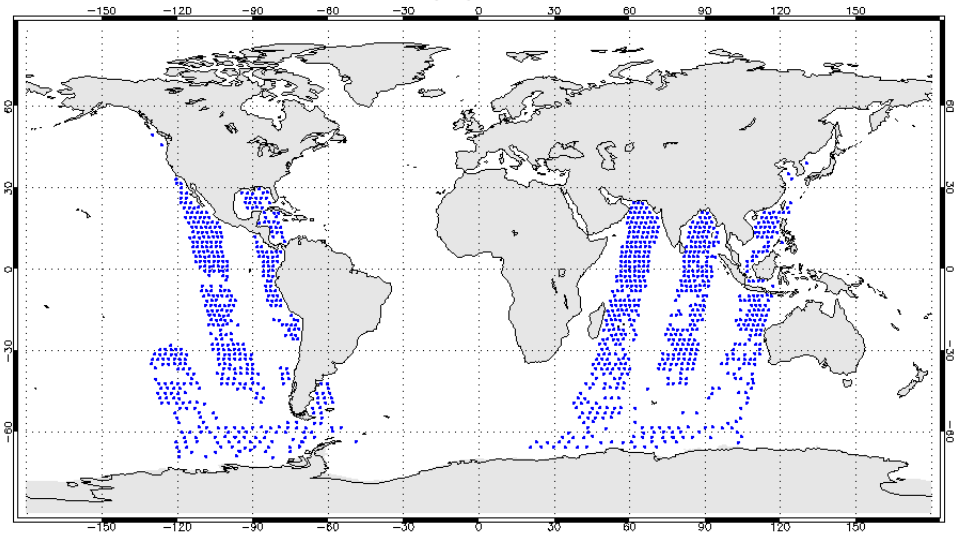
AMSU-A/B



AIRS



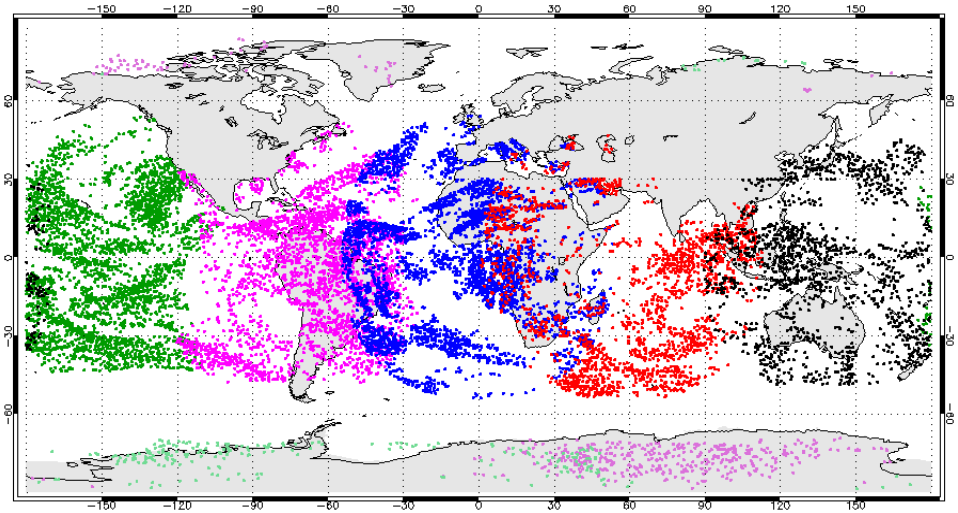
SSM/I



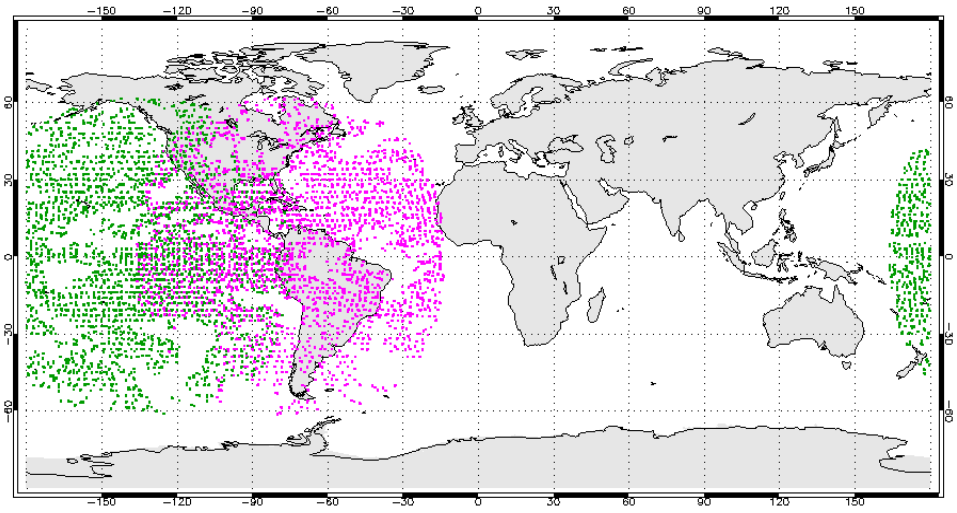
Passive remote sensing observations

(geostationary satellites)

AMVs

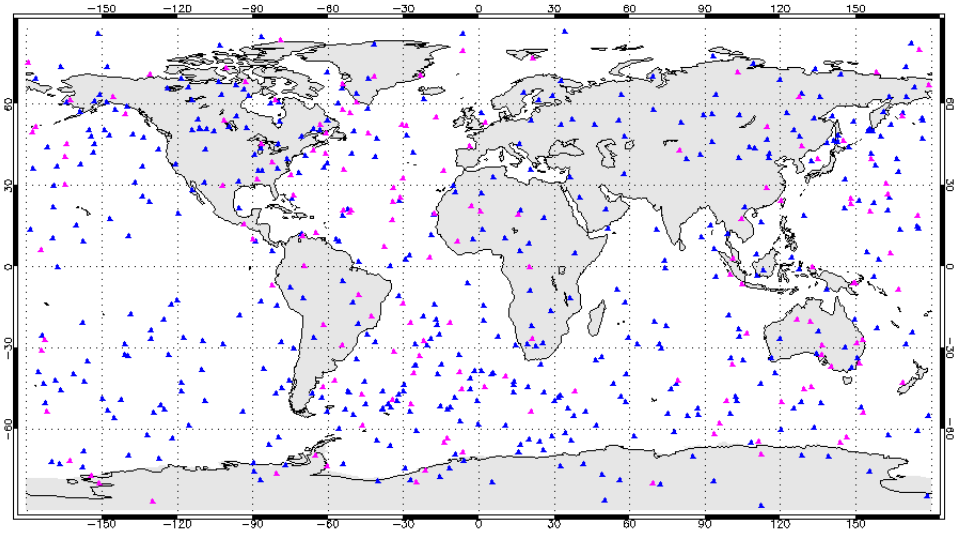


GOES radiances

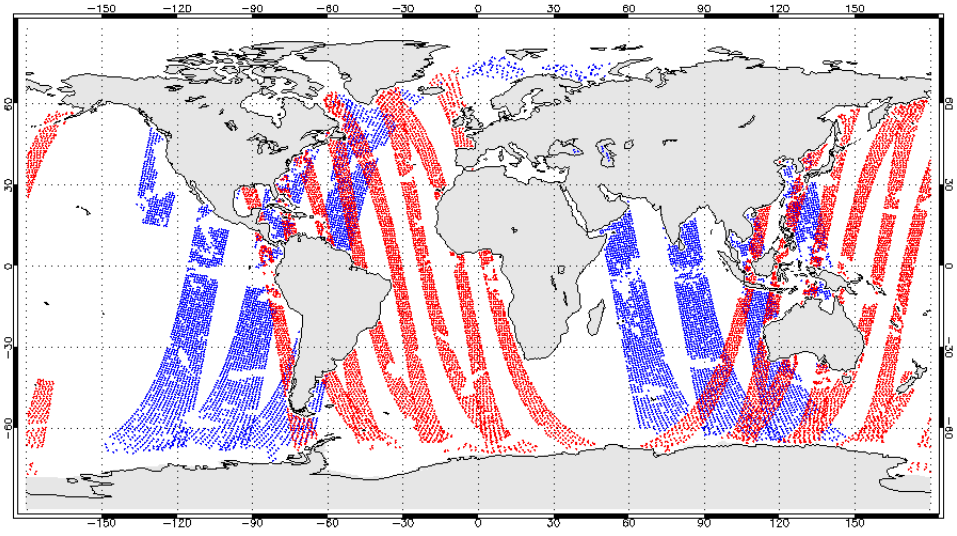


Active remote sensing observations

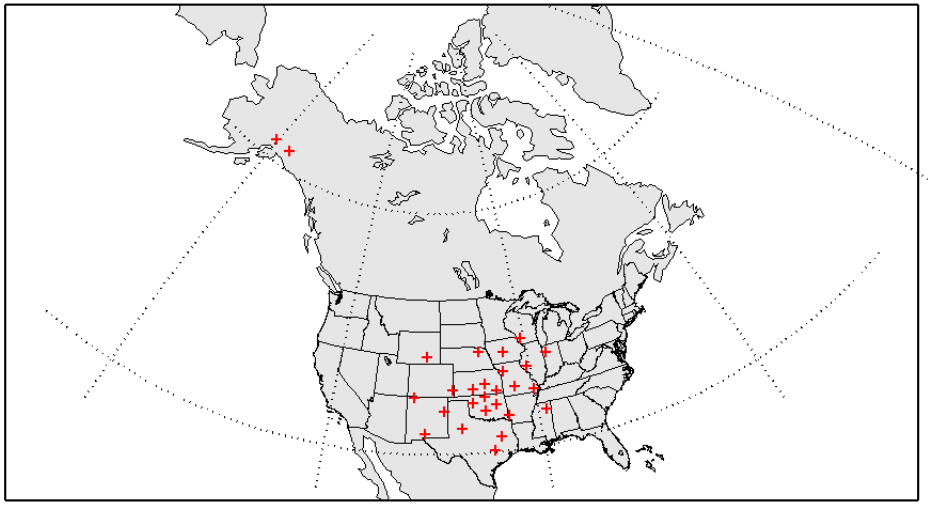
GPS-RO



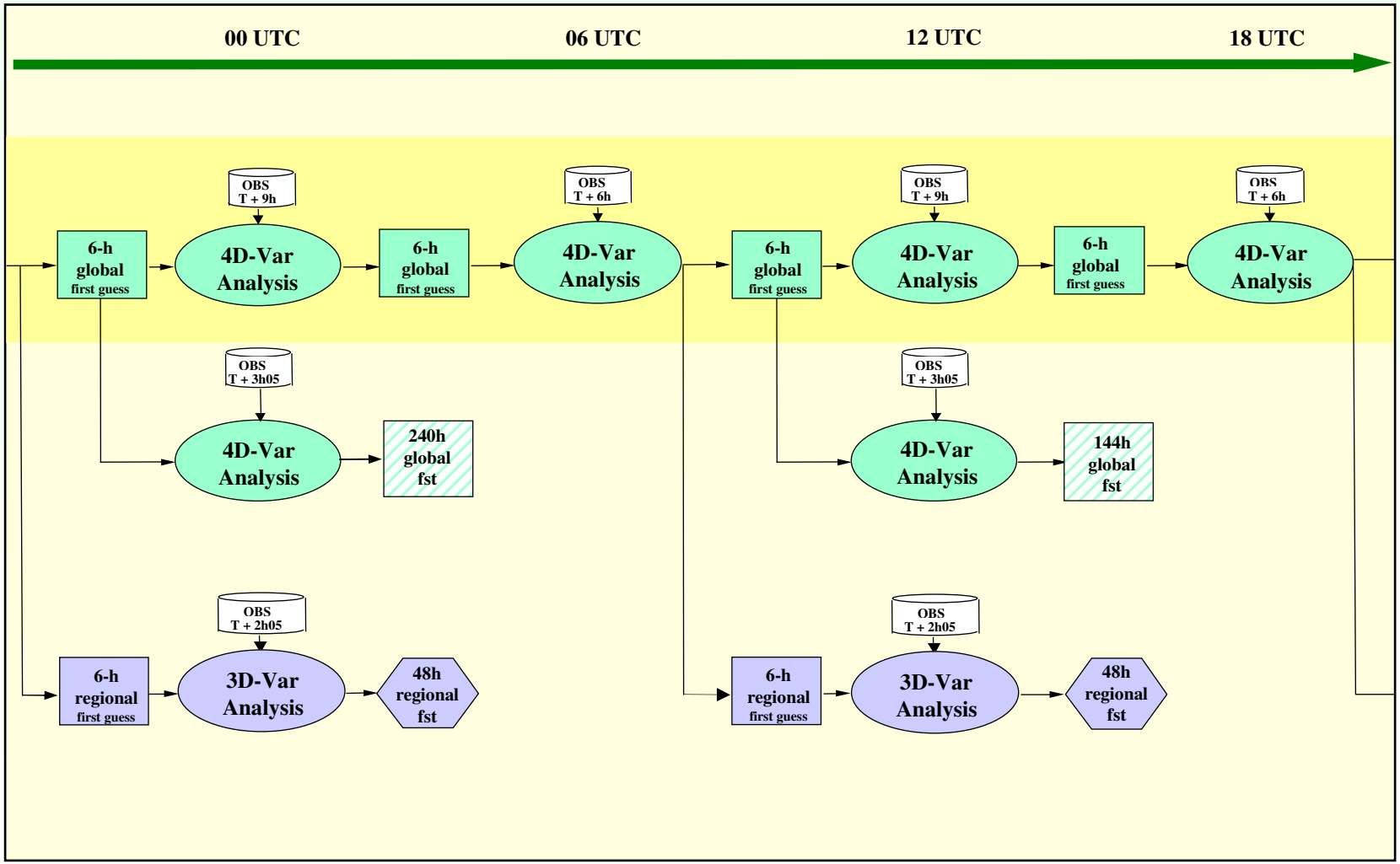
Scatterometers



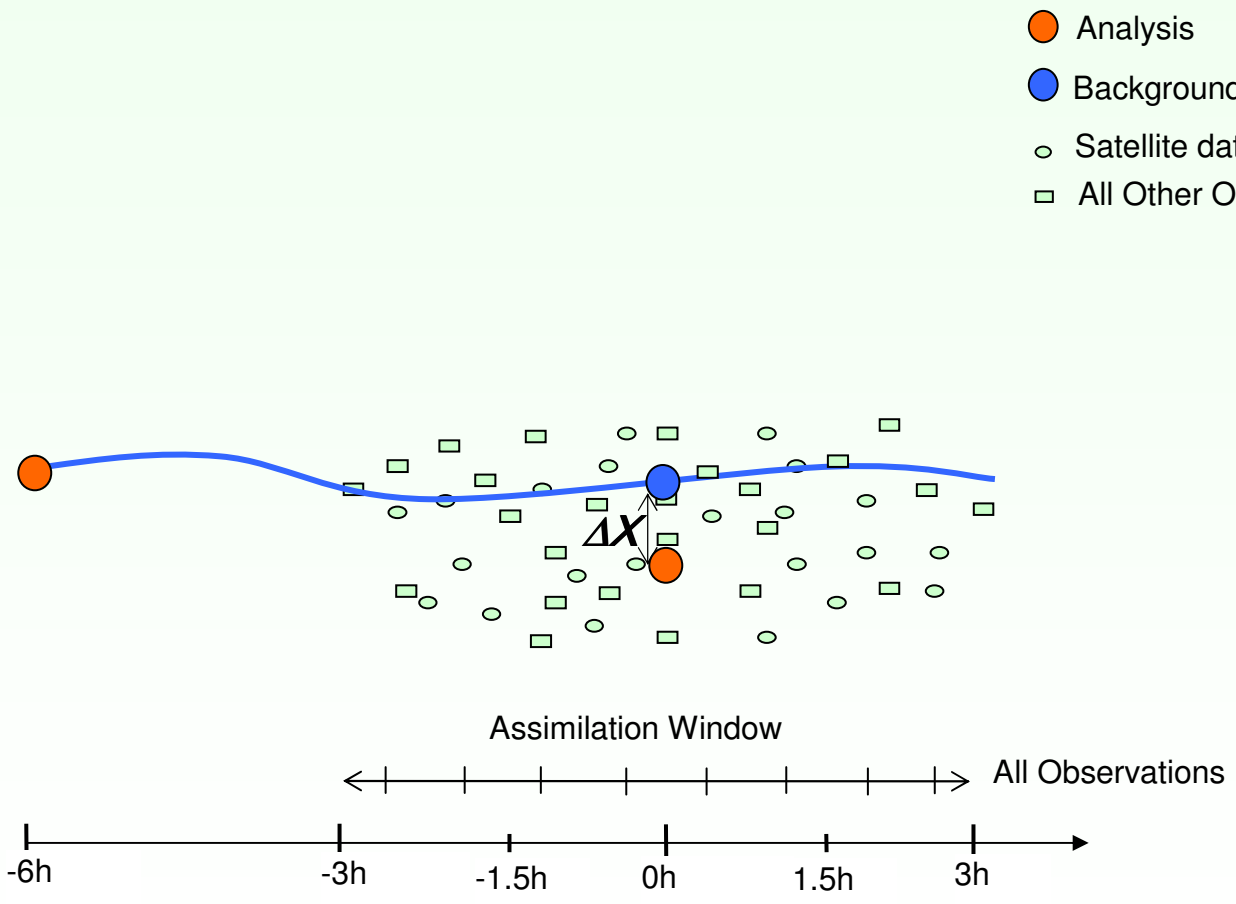
Wind profilers



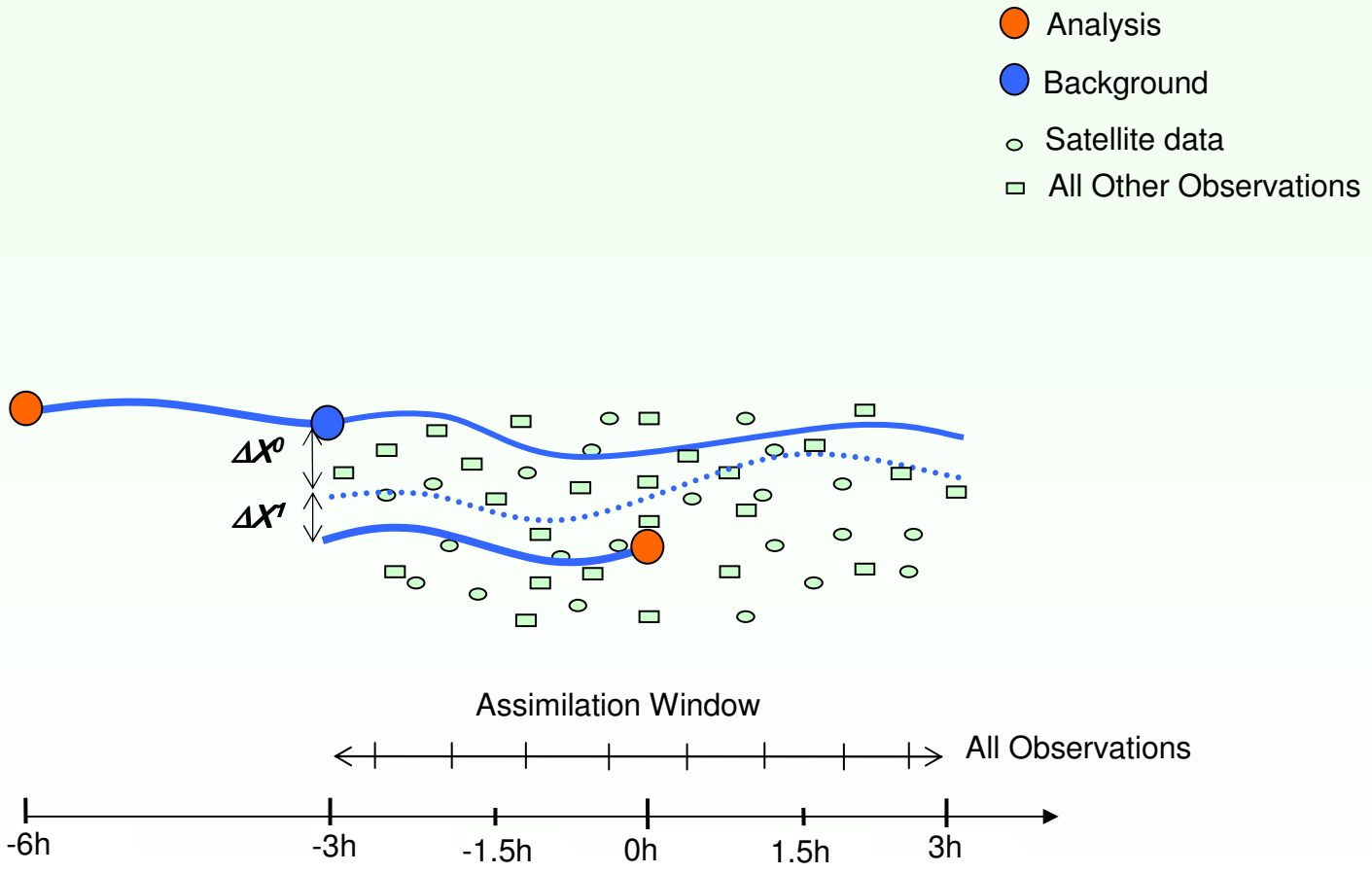
MSC Global and Regional forecast systems



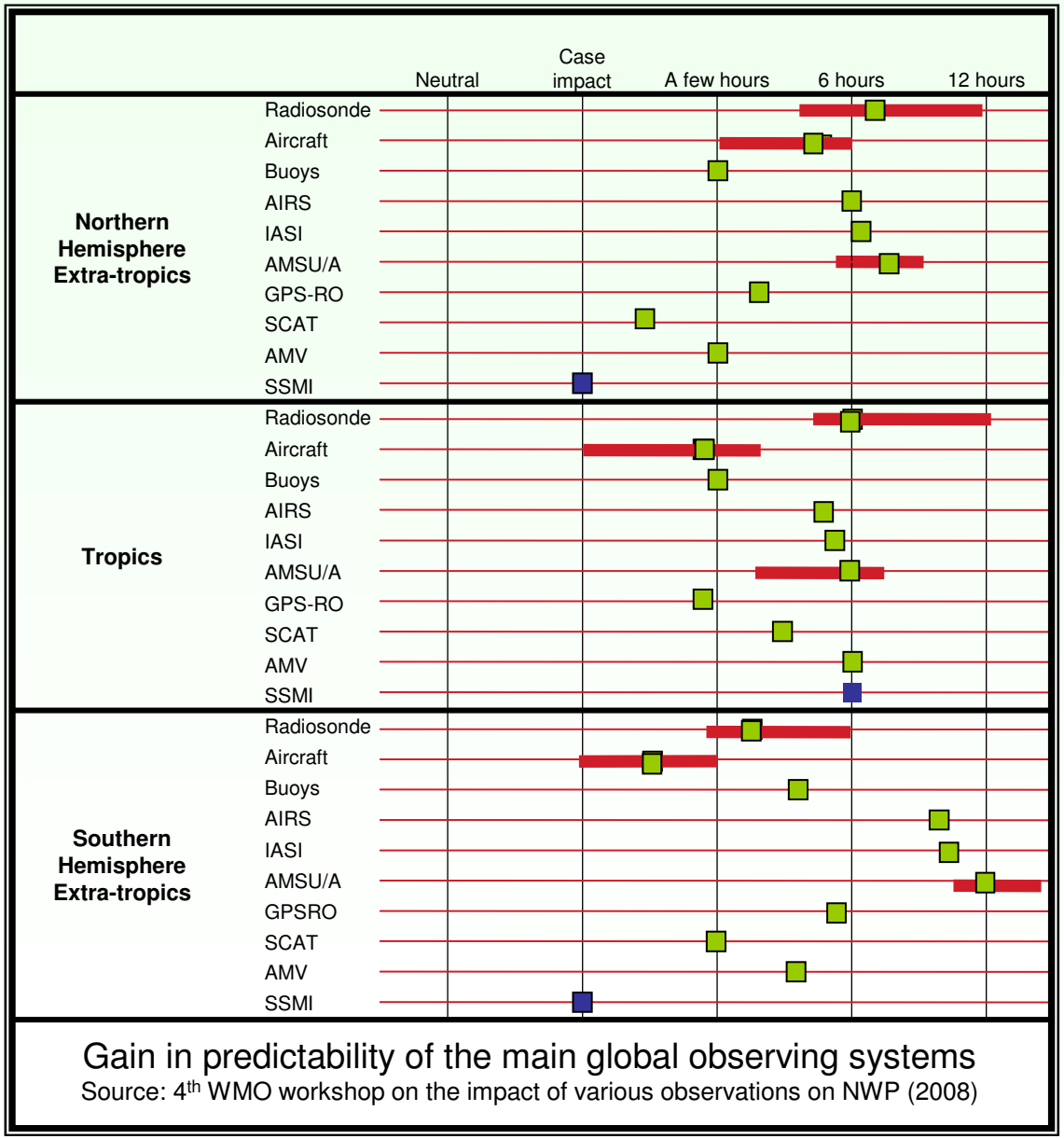
3D-Var (FGAT)


Analysis
Background
Satellite data
All Other Observations
ΔX
Assimilation Window
All Observations
-6h
-3h
-1.5h
0h
1.5h
3h

4D-Var

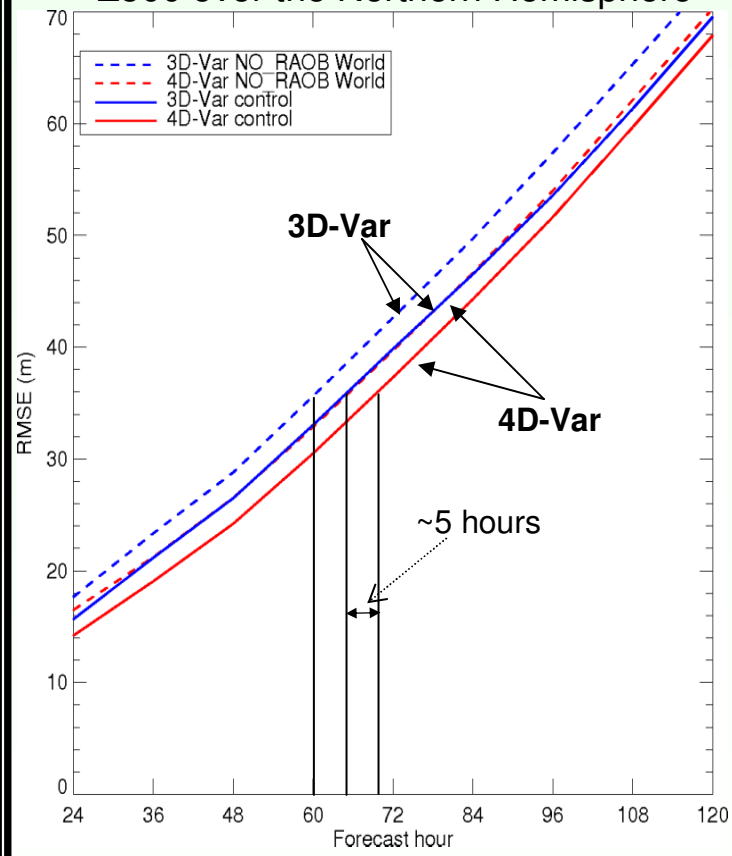

Analysis
Background
Satellite data
All Other Observations
ΔX^0
ΔX^1
Assimilation Window
All Observations
-6h
-3h
-1.5h
0h
1.5h
3h

Impact of the main global observing systems in terms of gain in predictability



Gain in predictability of the main global observing systems

Source: 4th WMO workshop on the impact of various observations on NWP (2008)

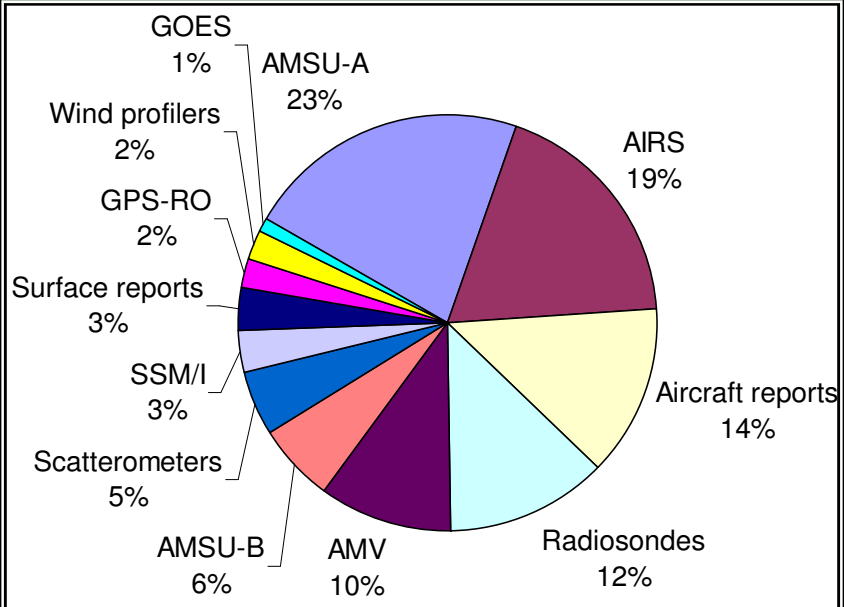


Results from OSEs conducted with the MSC global forecast system January and February 2007

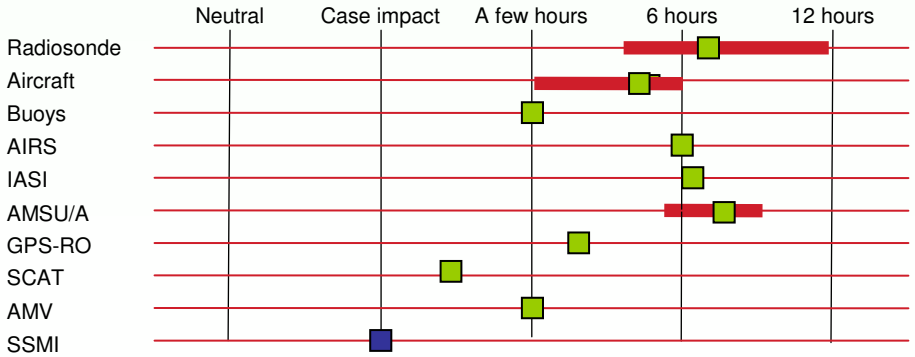
Observations assimilated in the MSC global forecast system

(March 2009)

About 1.6 million observations are assimilated in the global forecast system daily



Distribution of the various data type assimilated at 00 and 12 UTC



Gain in predictability for various observations in the Northern Hemisphere

Some relevant questions

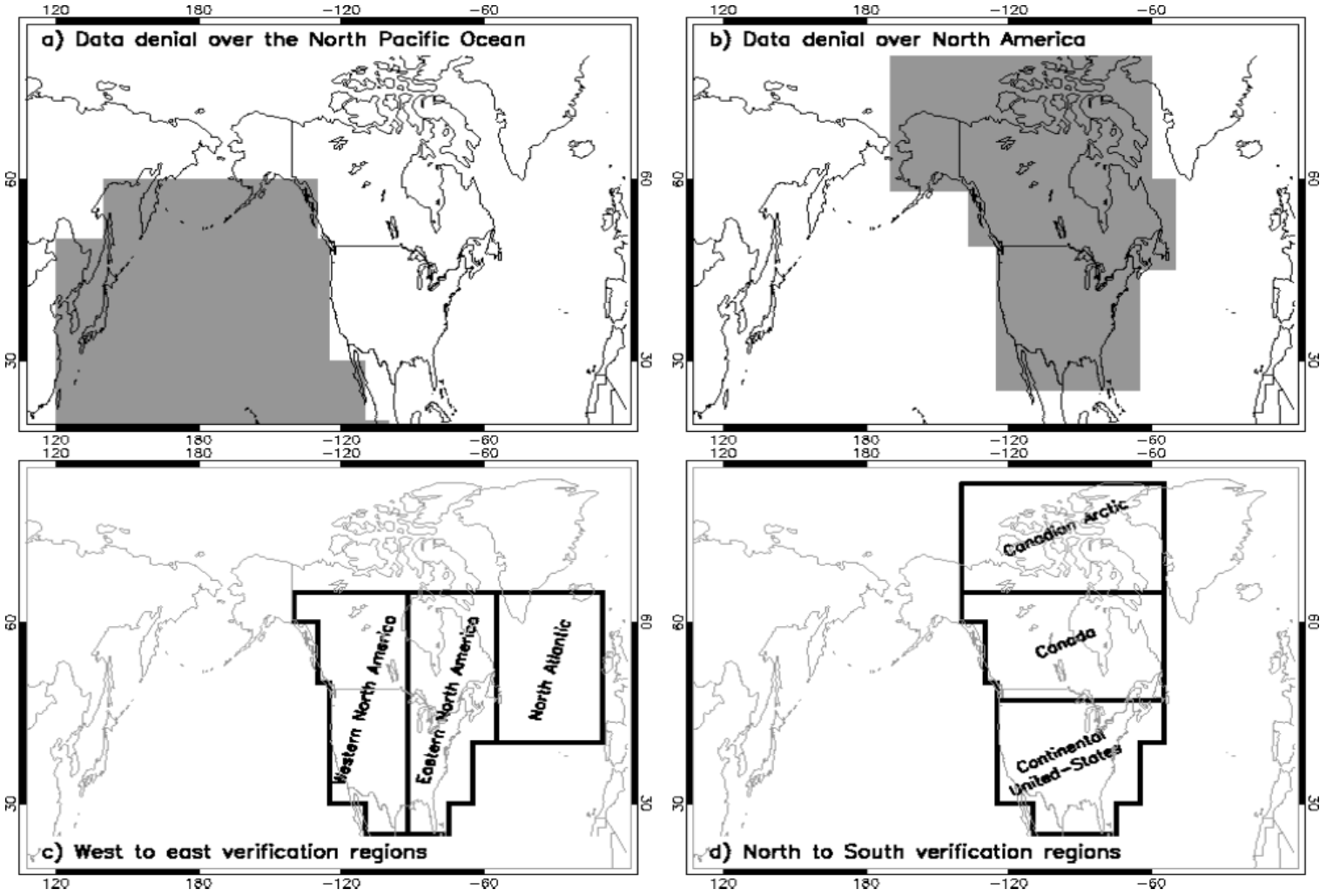
- Which components of the global observing system are most important over North America at a given forecast range?
- How the impact is distributed in space and time over Canada, the United-States and the Canadian Arctic ?
- How sensitive are the results with respect to the data assimilation scheme, the horizontal resolution of the forecast model and the weather regime?

Observing System Experiments

(January and February 2007)

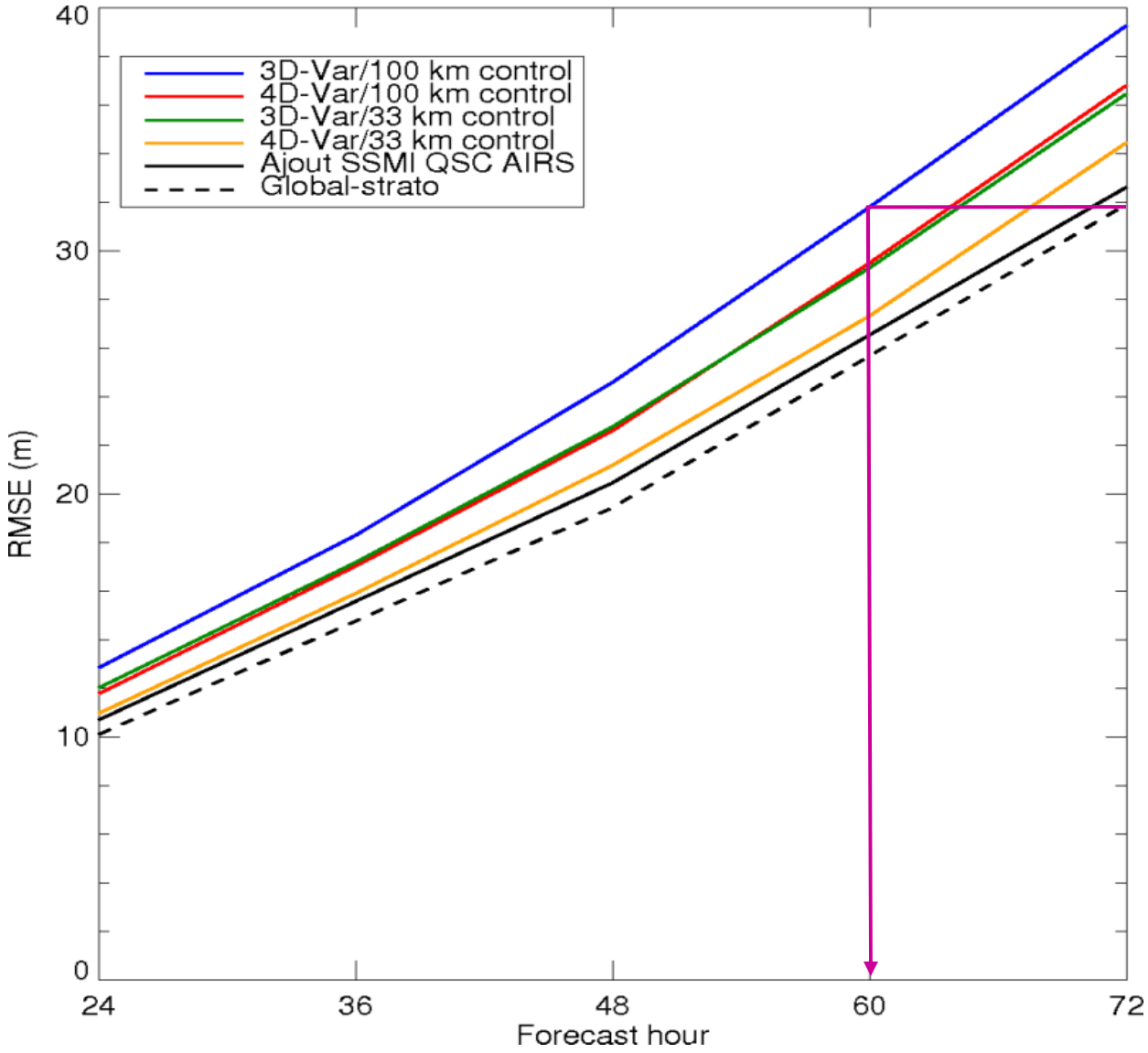
Experiment	Data type denied	Region where data are denied	Data assimilation scheme	Horizontal resolution of the forecast model
NO_RAOBS +NO_AIRCRAFT	Radiosonde Aircraft	North America	4D-Var	100 km
NO_AIRCRAFT	Aircraft	North America	4D-Var	100 km
NO_RAOBS	Radiosonde	North America	4D-Var	100 km
NO_SAT	Satellite	North Pacific	4D-Var	100 km
NO_SAT North America	Satellite	North America	4D-Var	100 km
NO_PROFILER	Wind profiler	North America	4D-Var	100 km
NO_RAOBS	Radiosonde	North America	3D-Var	100 km
NO_AIRCRAFT	Aircraft	North America	3D-Var	100 km
NO_SAT	Satellite	North Pacific	3D-Var	100 km
NO_RAOBS Word	Radiosonde	World	4D-Var	100 km
NO_RAOBS Word	Radiosonde	World	3D-Var	100 km
NO_AIRCRAFT	Aircraft	North America	4D-Var	33 km
NO_AIRCRAFT	Aircraft	North America	3D-Var	33 km
4D-Var/100 km Control	-	-	4D-Var	100 km
3D-Var/100 km Control	-	-	3D-Var	100 km
4D-Var/33 km Control	-	-	4D-Var	33 km
3D-Var/33 km Control	-	-	3D-Var	33 km

Data denial and verification regions



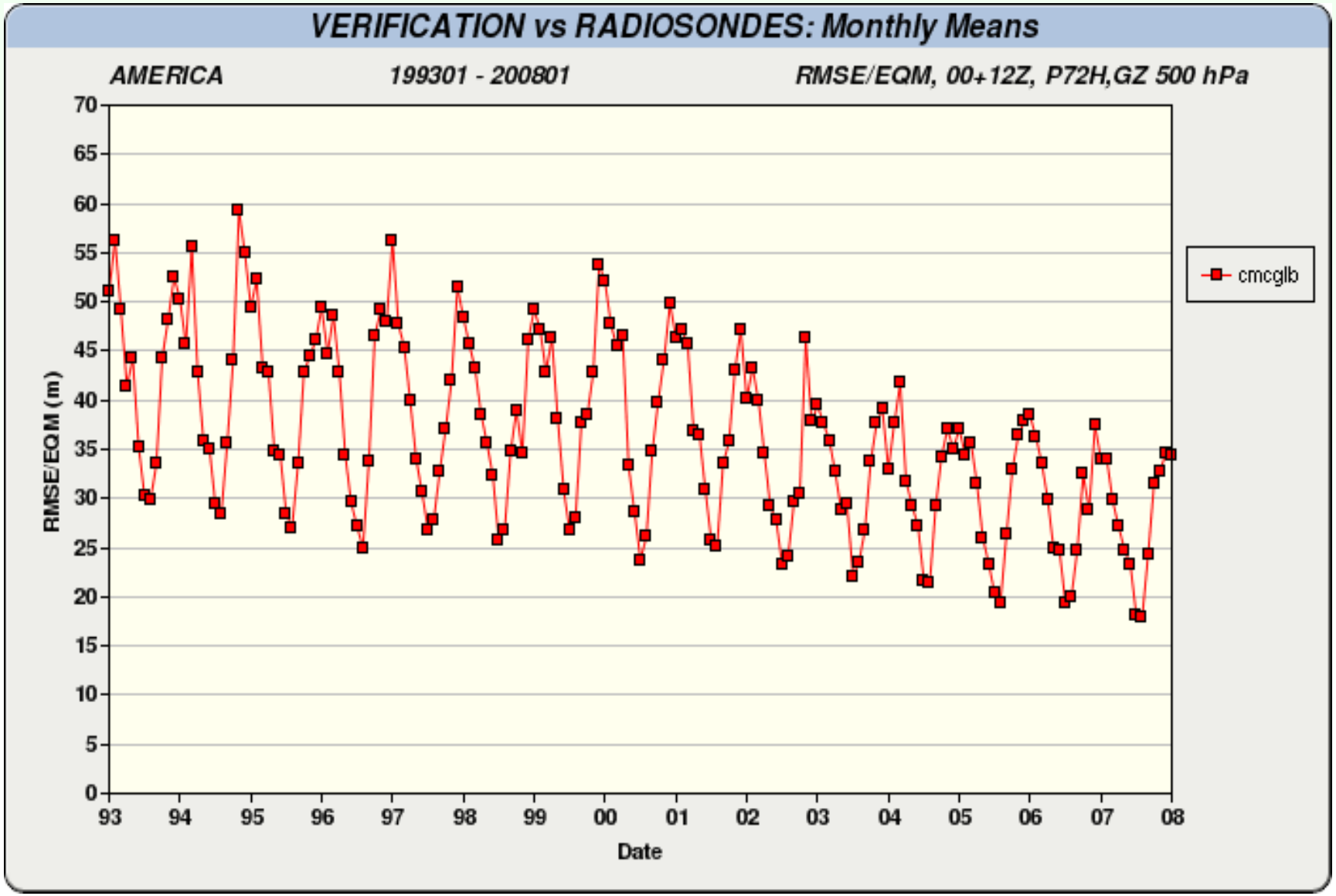
North America Z500 RMSE for the control experiments and latest upgrades of the MSC global analysis-forecast system

(January and February 2007)



72h forecast Z500 RMSE for the MSC global forecast system over North America against radiosondes

(1993-2008)



Forecast RMSE reduction for Z500 over North America in the MSC forecast systems over the recent years

$$\mathrm{FI} = 100 \times \frac{RMSE(\text{exp}) - RMSE(\text{cnt})}{RMSE(\text{cnt})}$$

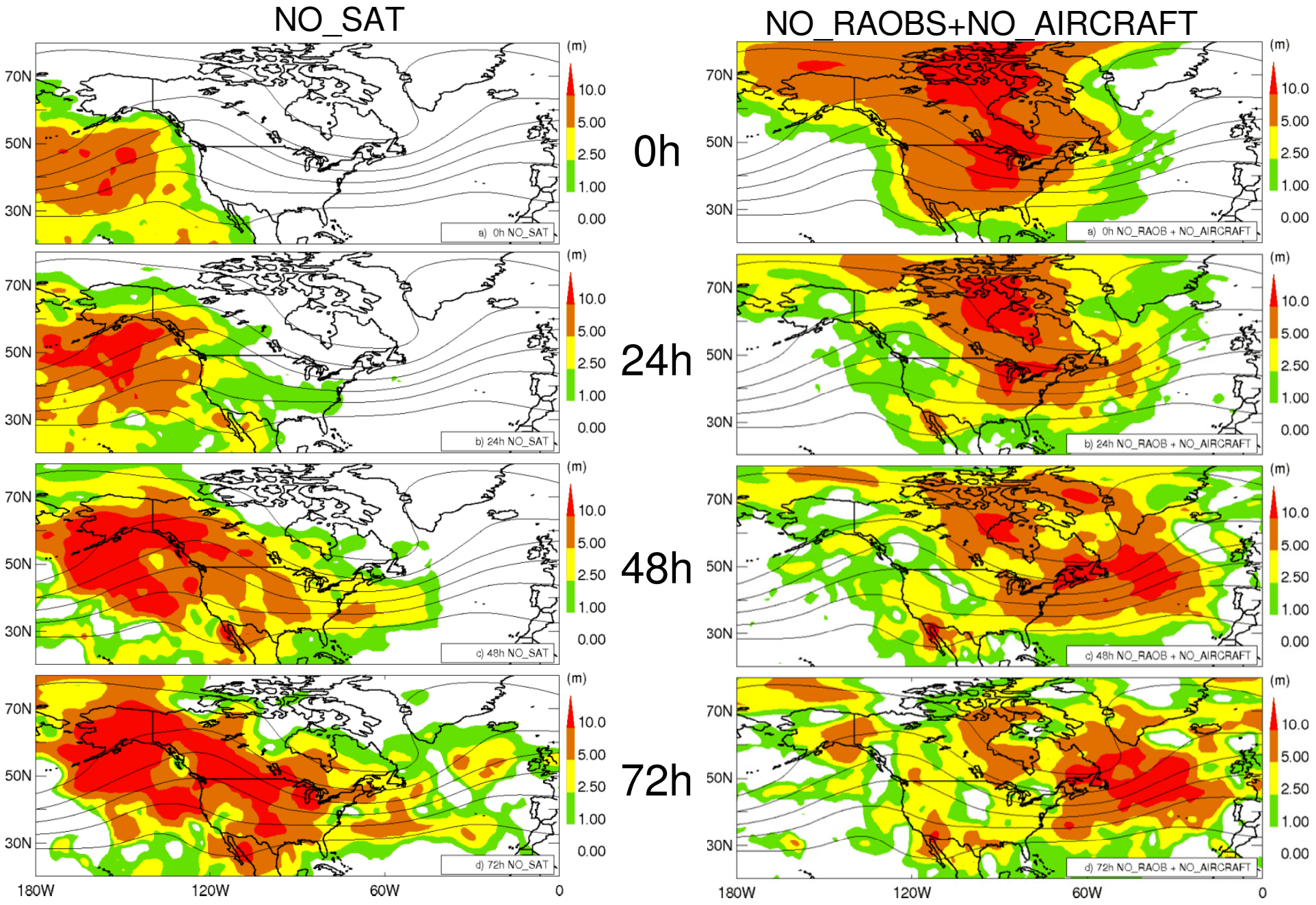
Verifications made against radiosonde observations

Years	24h	48h	72h
2003 vs 2008	15%	21%	25%
1999 vs 2008	45%	43%	45%
1993 vs 2008	62%	65%	60%

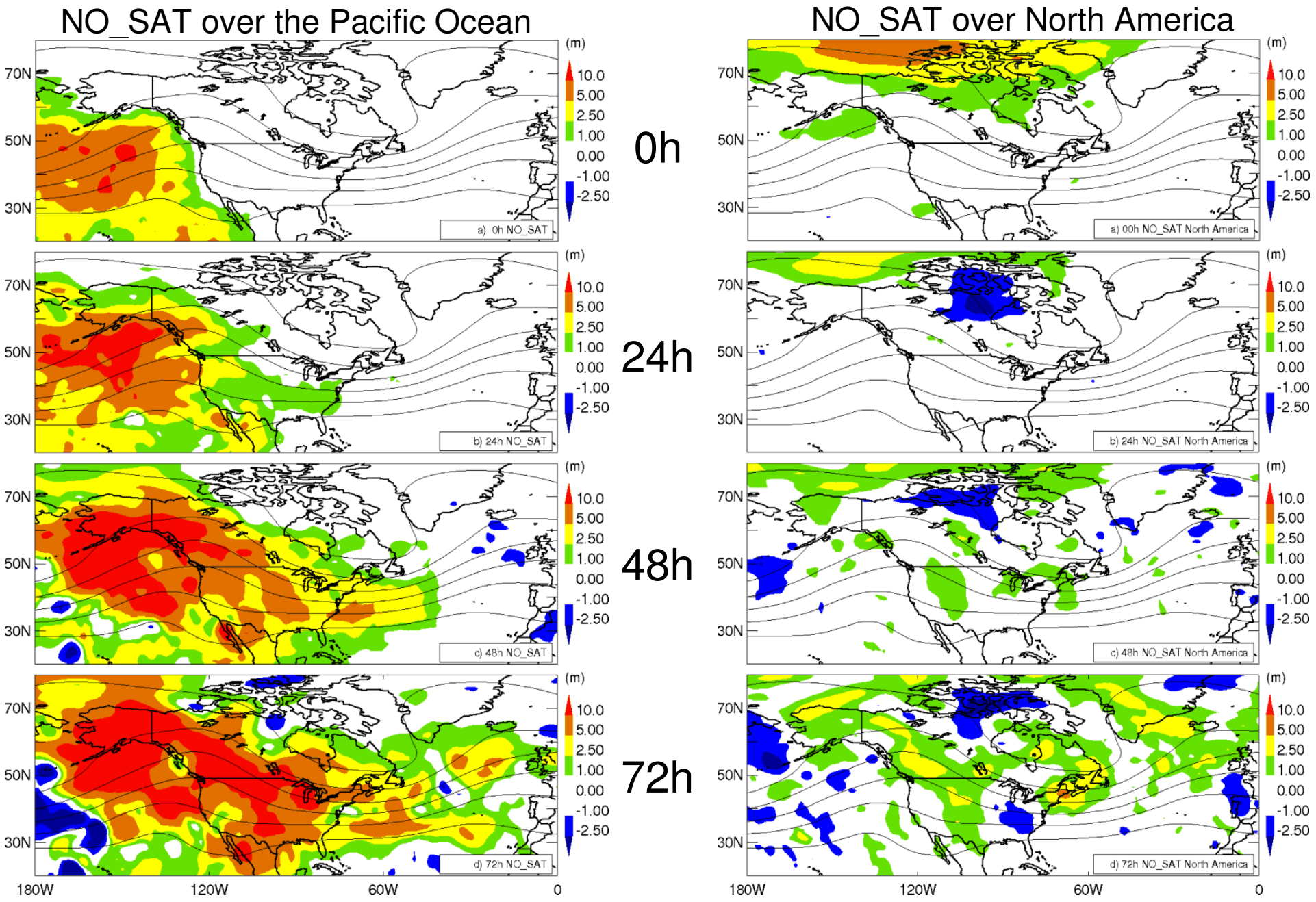
Verifications made against analyses from 'Ajout obs' (addition of SSMI, QS, AIRS)

Experiments	24h	48h	72h
4D-Var/33 km vs Ajout obs	3%	3%	5%
3D-Var/33 km vs Ajout obs	12%	11%	12%
4D-Var/100 km vs Ajout obs	9%	11%	13%
3D-Var/100 km vs Ajout obs	19%	20%	20%

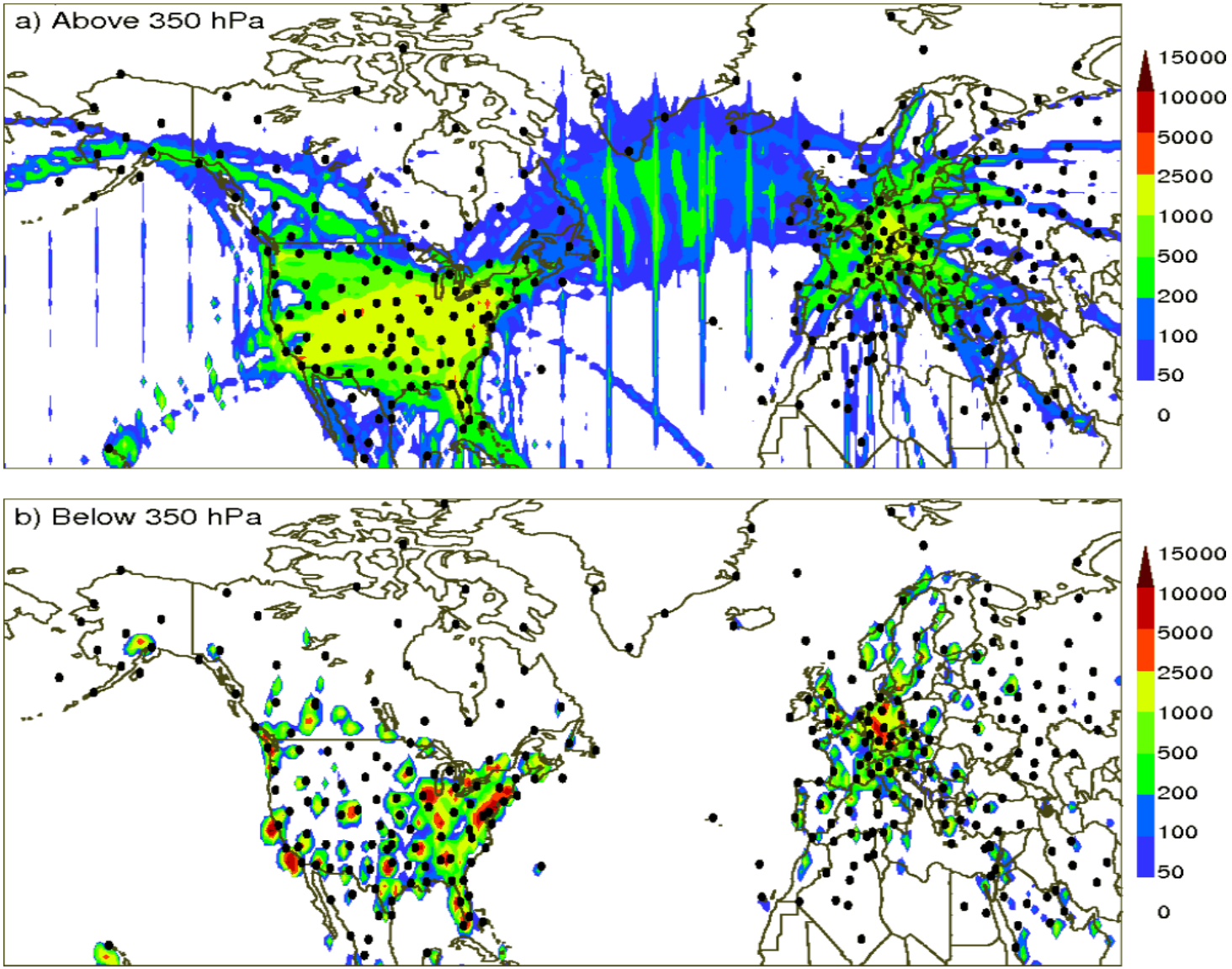
RMSE differences for Z500 (4D-Var/100 km)



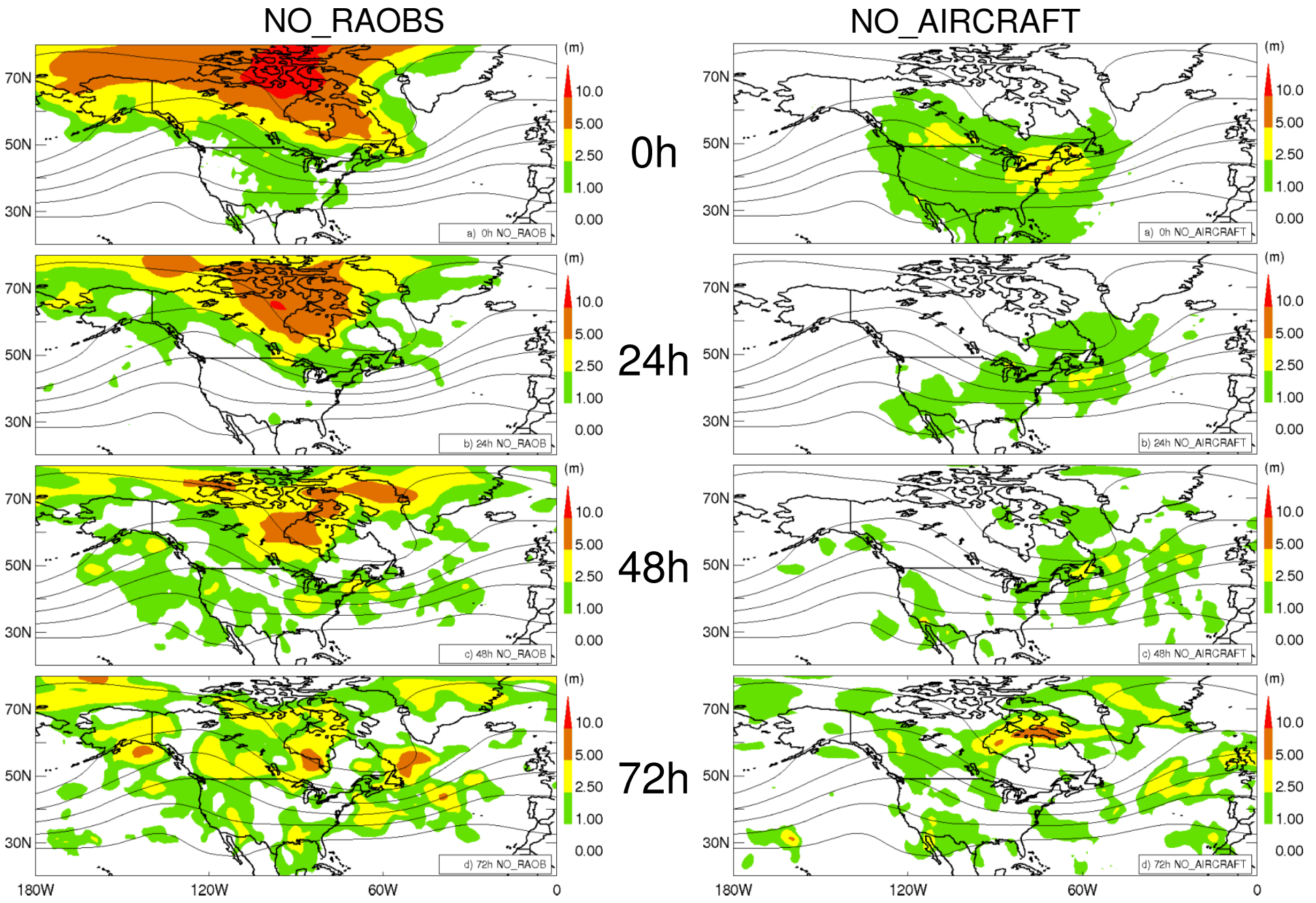
RMSE differences for Z500 (4D-Var/100km)



Aircraft reports assimilated during January and February 2007 and radiosonde stations (black dots)

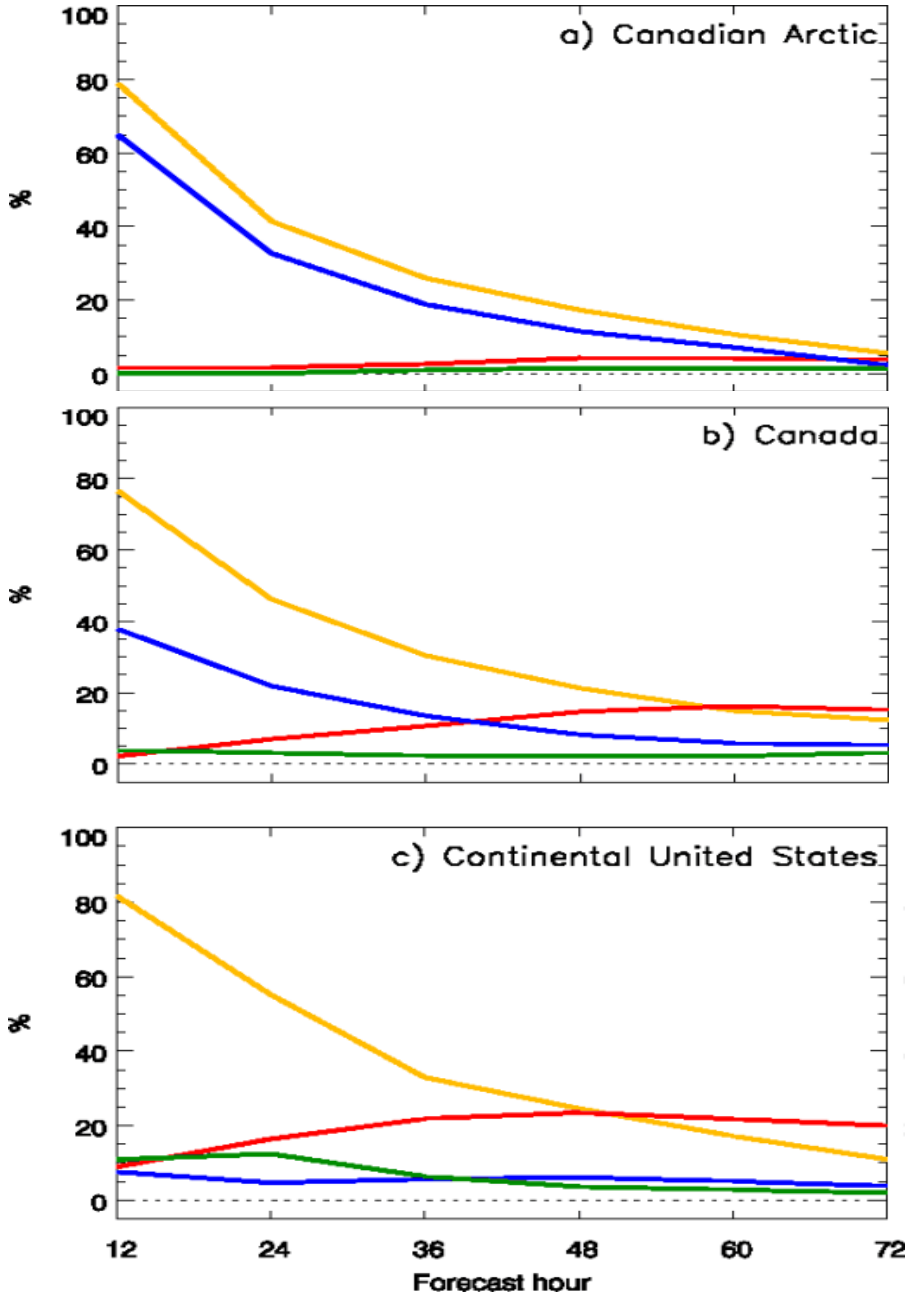


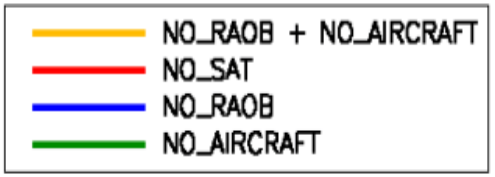
RMSE differences for Z500 (4D-Var/100 km)

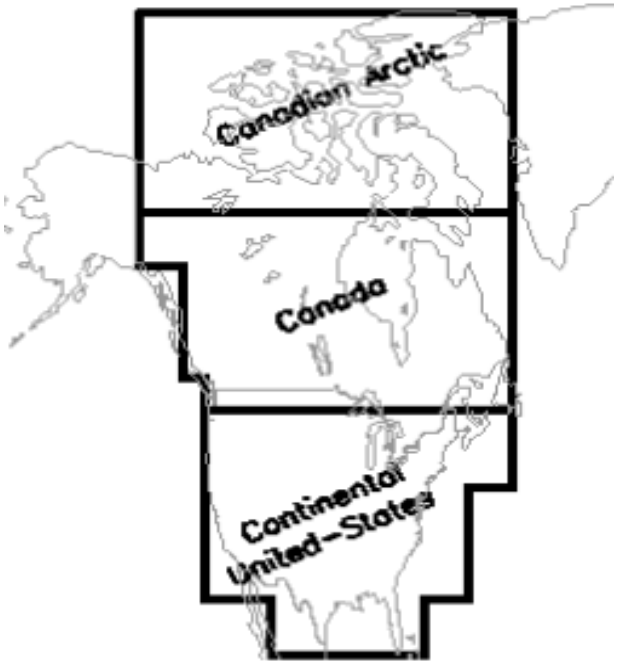


FIs over regions of North America and North Atlantic

Z500

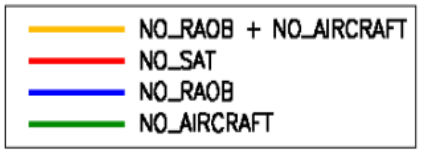


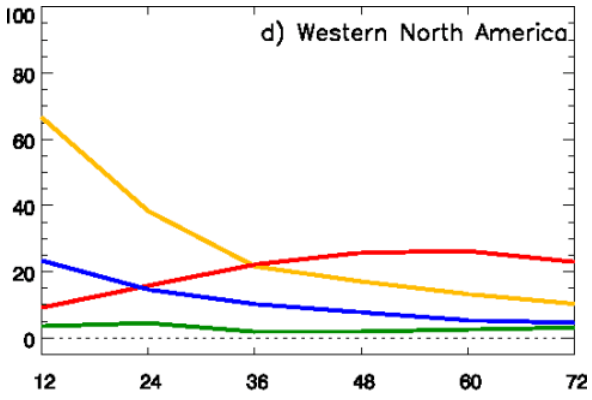


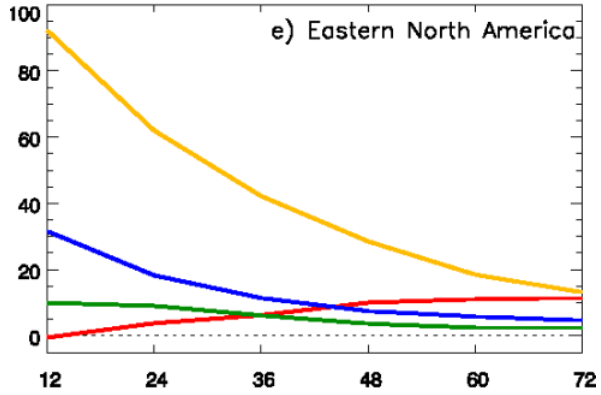


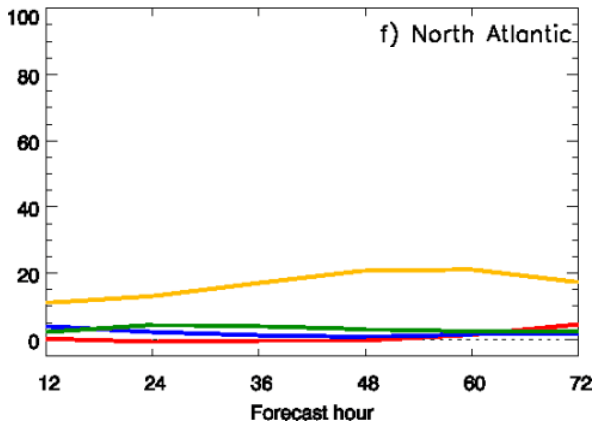
FIs over regions of North America and North Atlantic

Z500

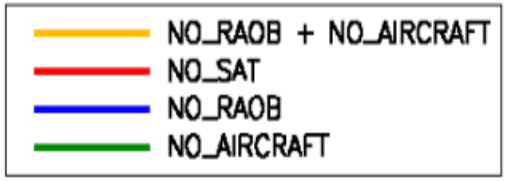




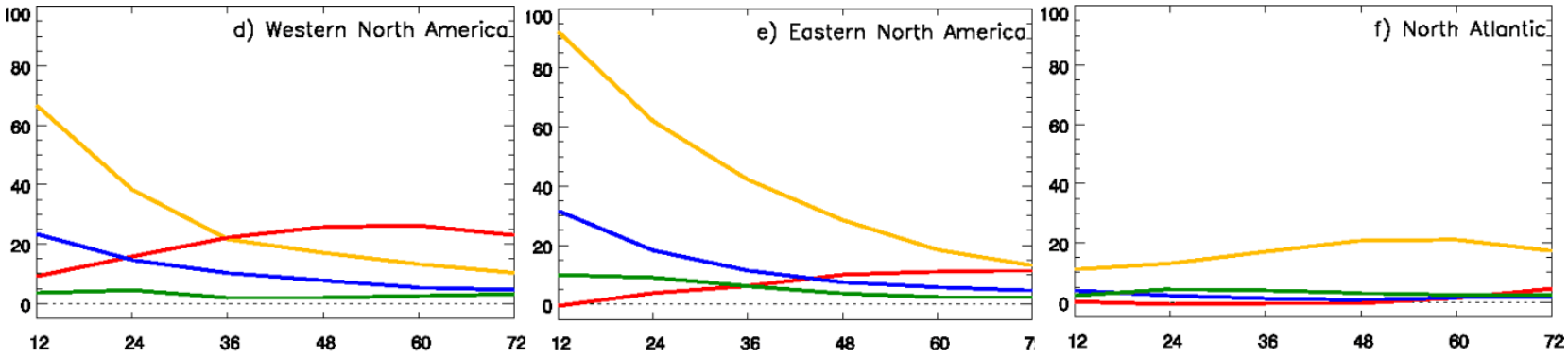




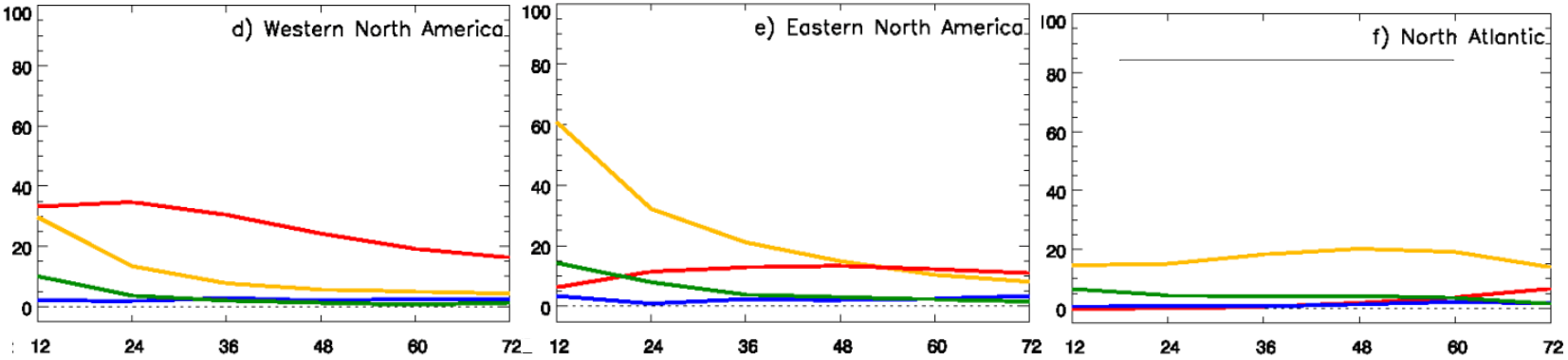
FIs over regions of North America and North Atlantic



Z500

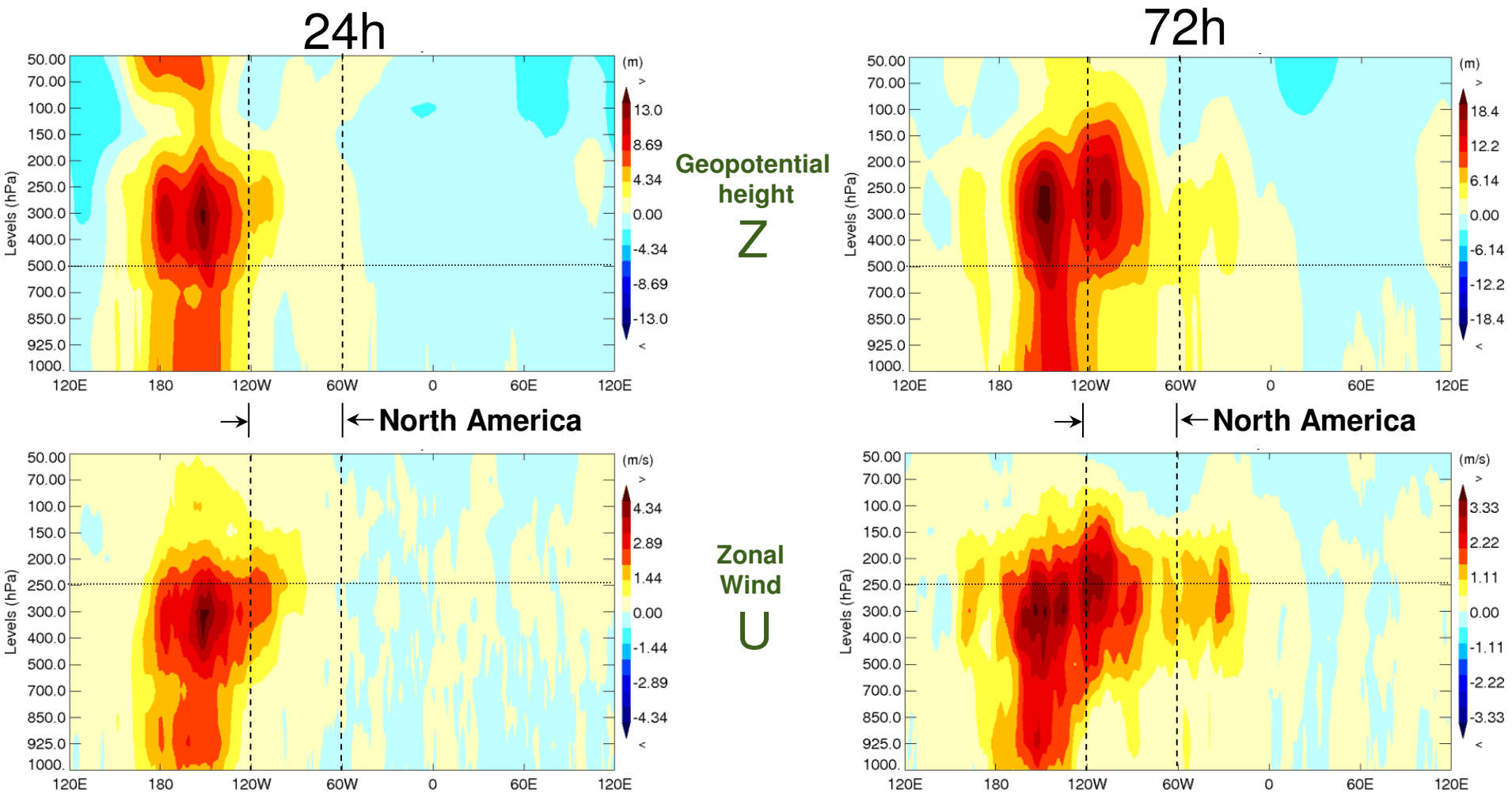


U250

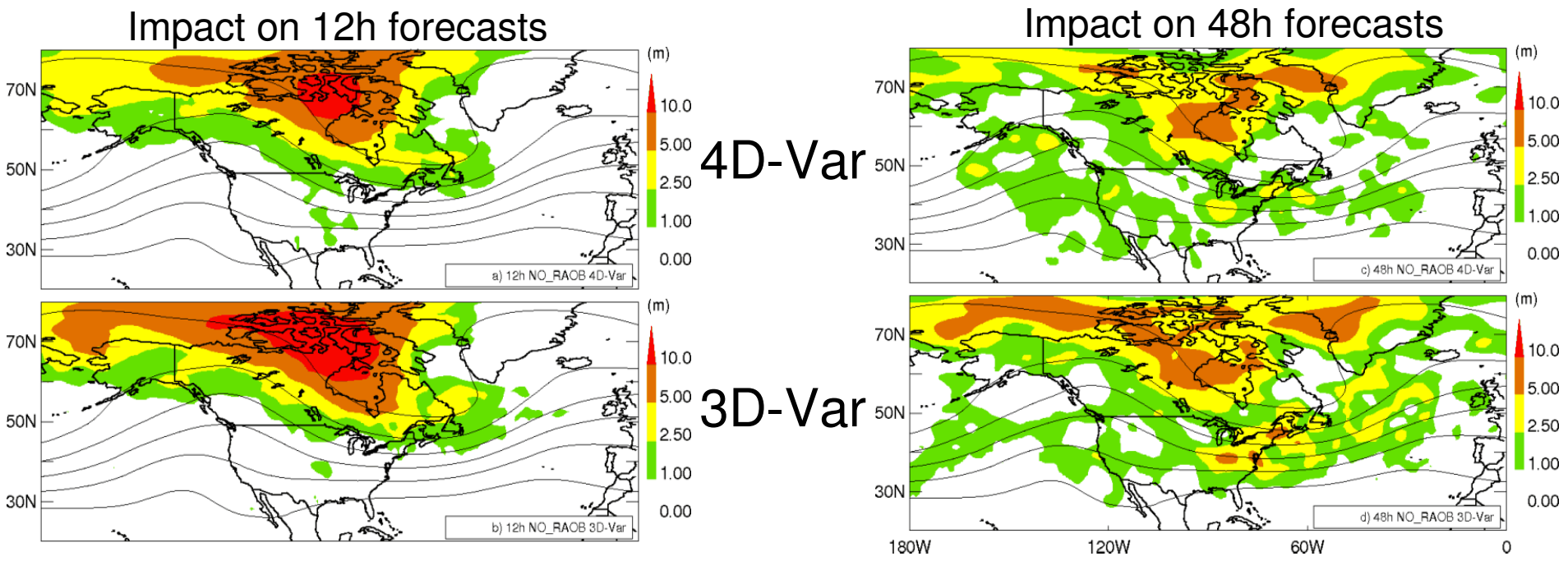


Impact cross-sections in the northern mid-latitudes

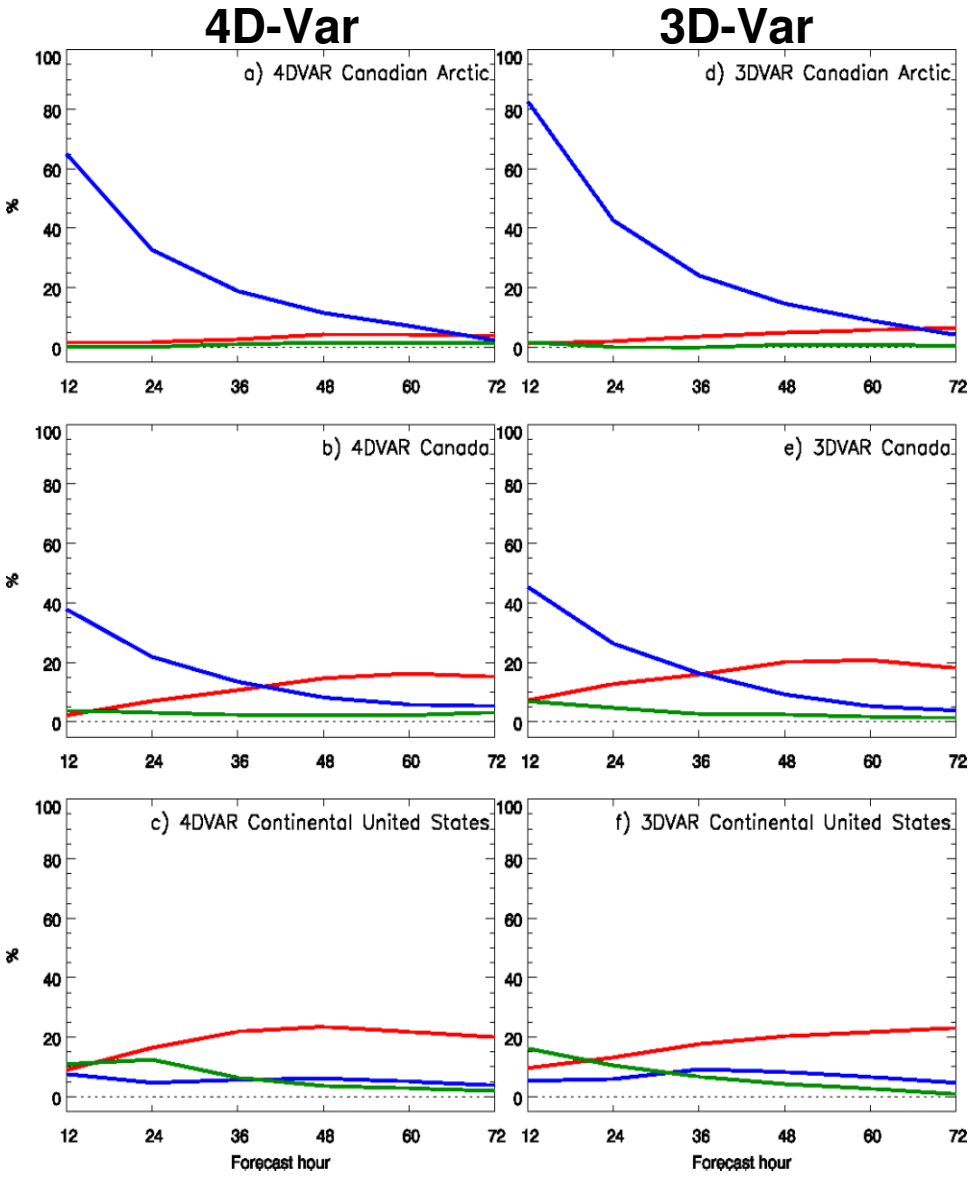
NO_SAT over the Pacific Ocean (4D-Var/100 km)

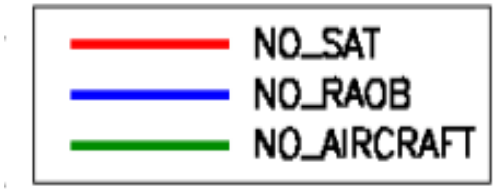


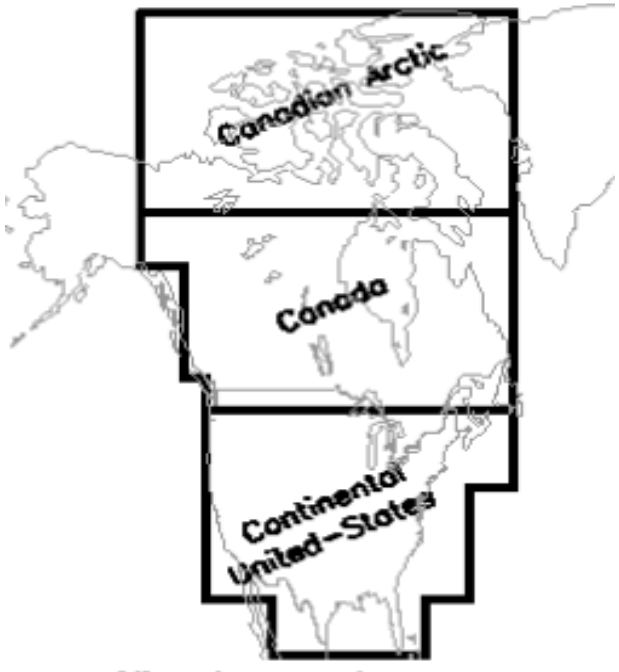
Comparison 3D-Var and 4D-Var (100 km)
Z500 RMSE differences for radiosonde data



Comparison 3D-Var and 4D-Var (100 km)
Z500 FIs for radiosonde data

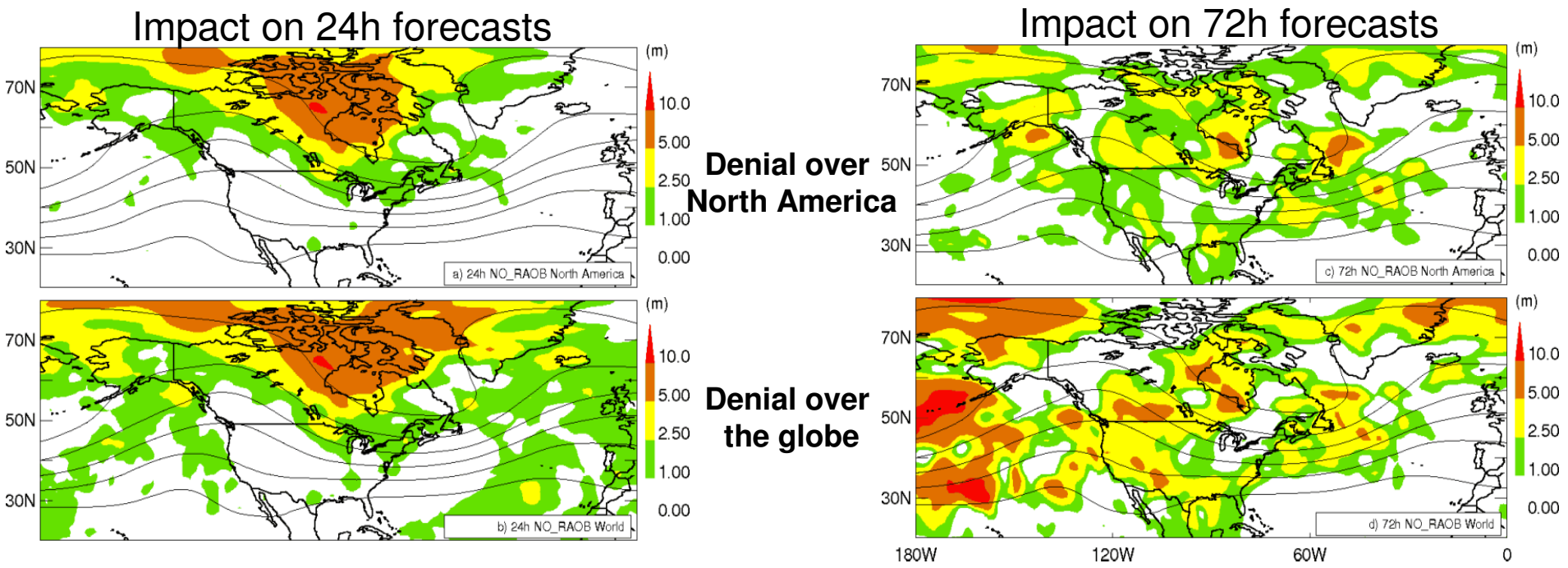






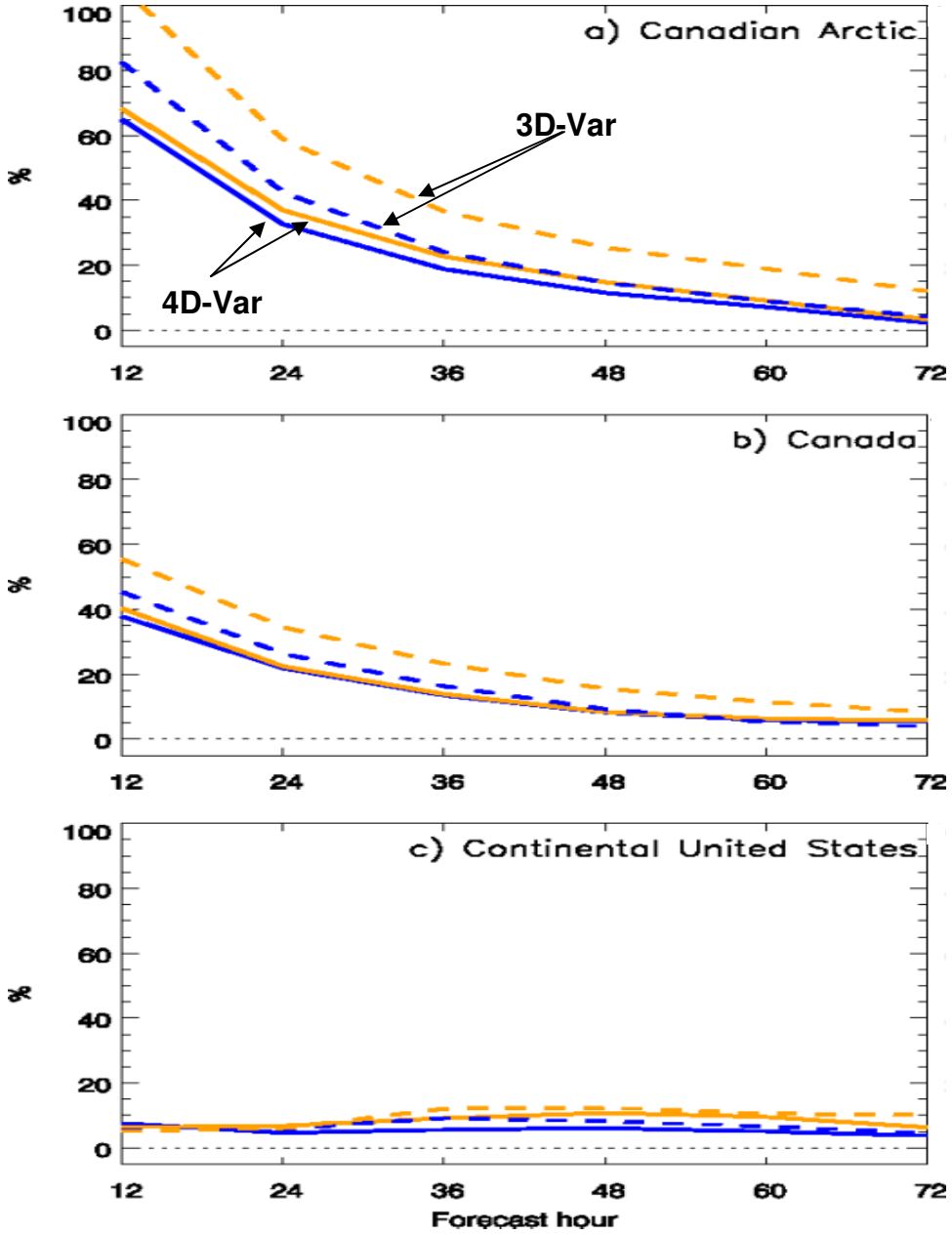
Impact of global and local (North America) data-denials

Z500 RMSE differences for radiosonde data (4D-Var/100 km) experiments

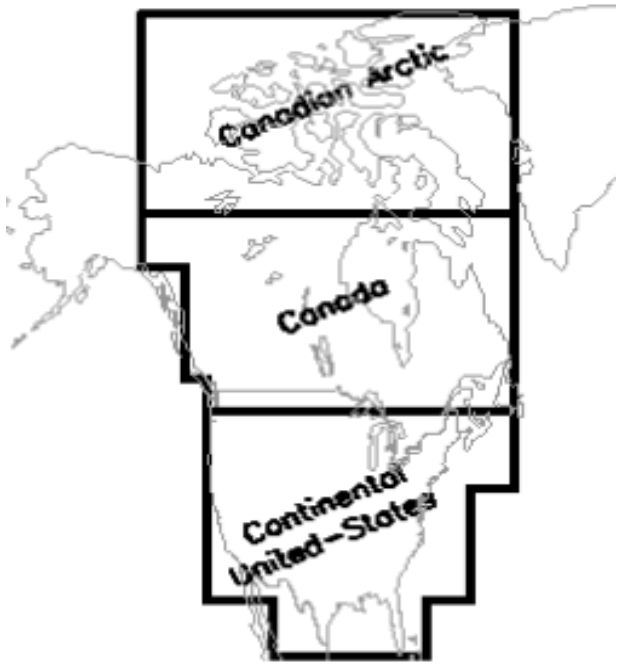


Impact of global and local (North America) data-denials

Z500 FIs for radiosonde data

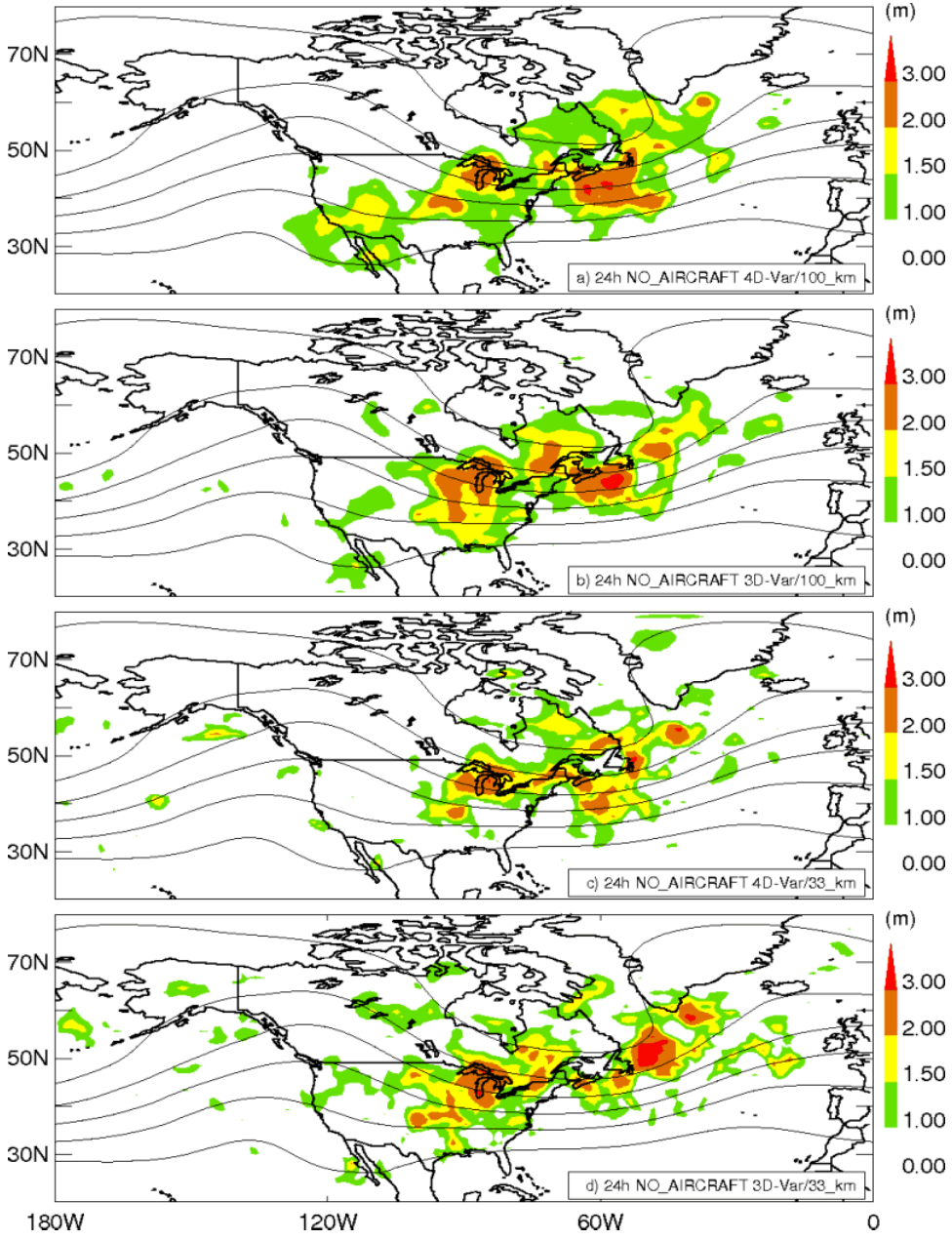


4D-Var NO_RAOB North America
4D-Var NO_RAOB Globe
3D-Var NO_RAOB North America
3D-Var NO_RAOB Globe



Sensitivity to analysis scheme and model horizontal resolution

24h Z500 RMSE differences for aircraft data denied over North America



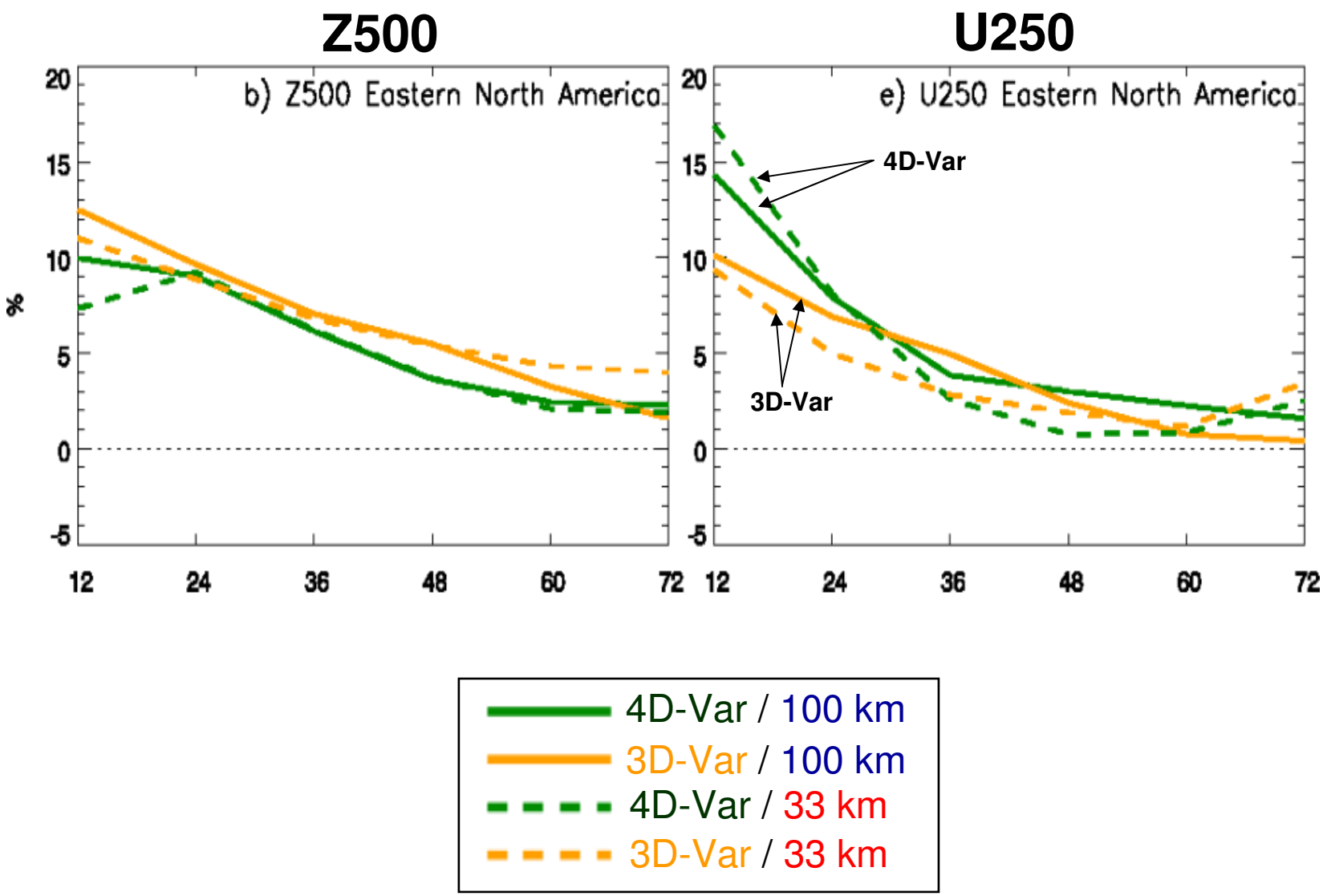
4D-Var / 100 km

3D-Var / 100 km

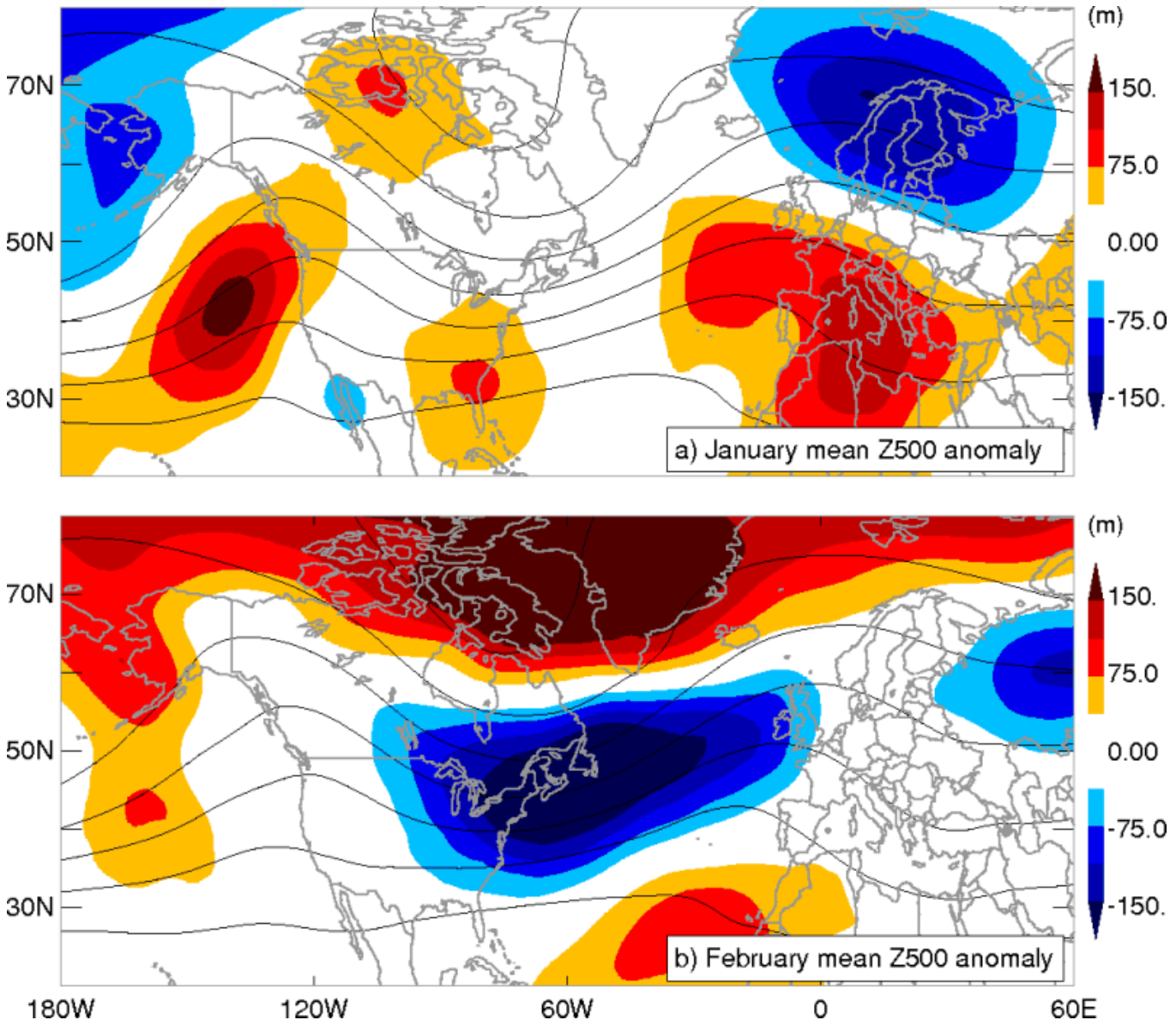
4D-Var / 33 km

3D-Var / 33 km

Sensitivity to analysis scheme and model horizontal resolution



Effect of the weather regime on the impacts
(mean Z500 anomaly for January and February 2007)

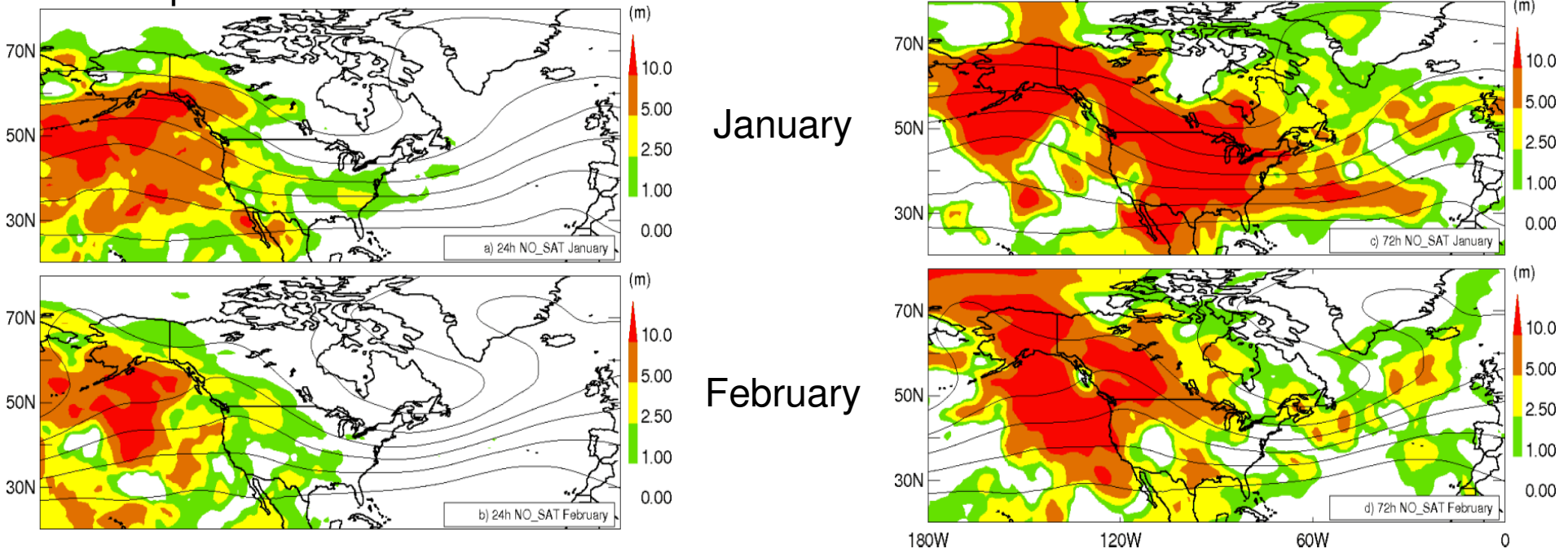


Effect of the weather regime on the impacts

(Z500 RMSE differences for NO_SAT experiment (4D-VAR/100 km))

Impact on 24h forecasts

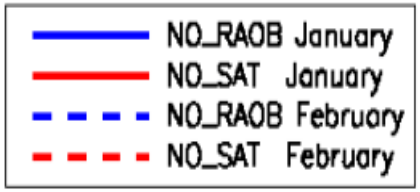
Impact on 72h forecasts

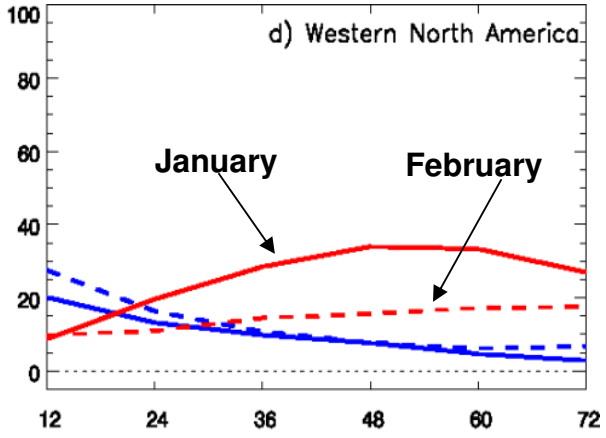


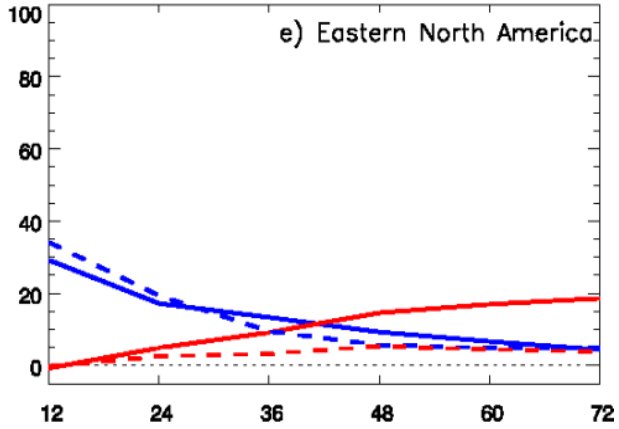
January

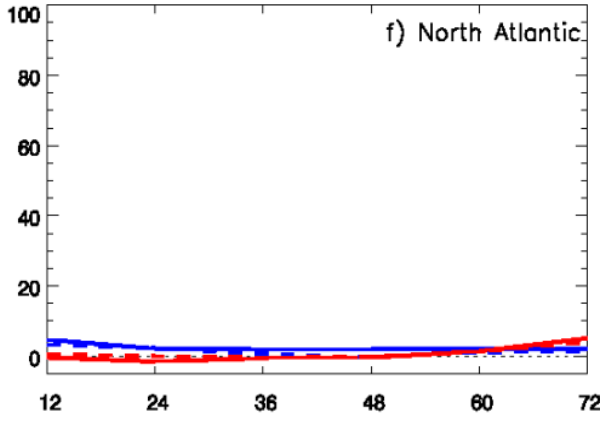
February

Effect of the weather regime on the impacts







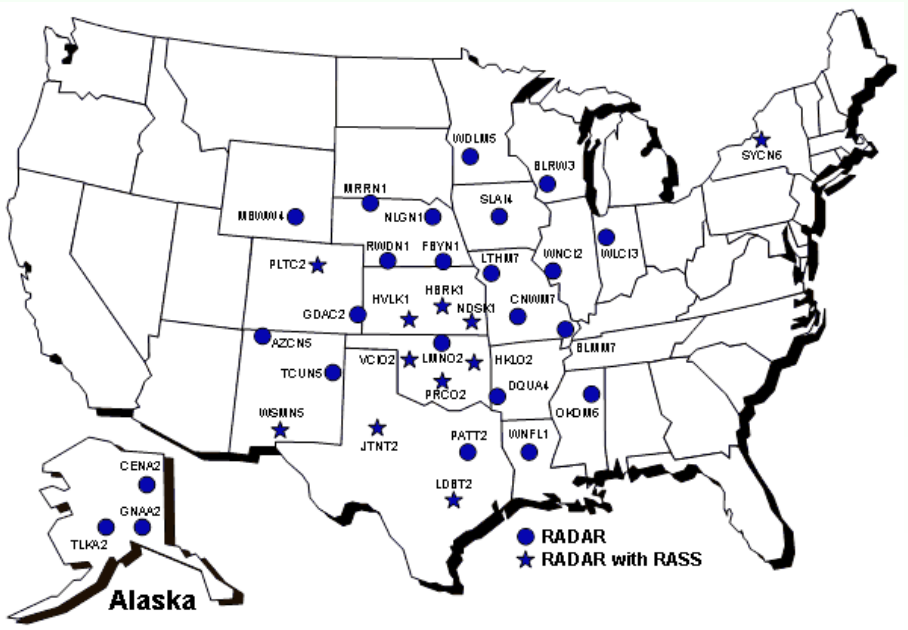


OSEs to assess the value of the NOAA wind profiler network

The impact of a given observing network can be assessed in two different ways:

1. By denying the observing network in the data assimilation cycle

2. By adding the observing network to a ‘baseline’ data assimilation cycle in which a minimum number of observations are assimilated to ensure a reasonable quality of the analyses and forecasts.

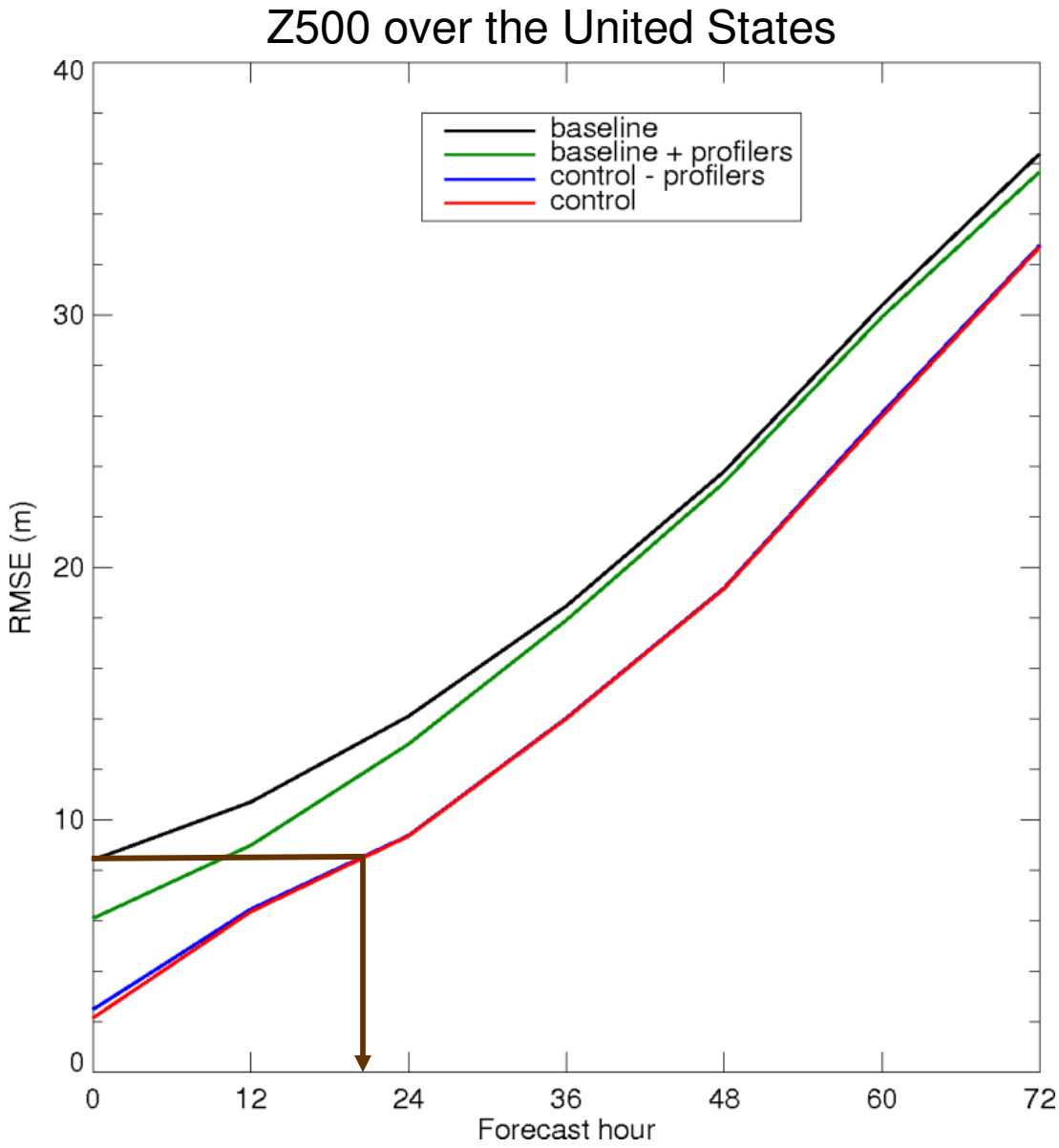


The value of the NOAA wind profiler network

(experiments NO_PROFILER (4D-Var/100 km)

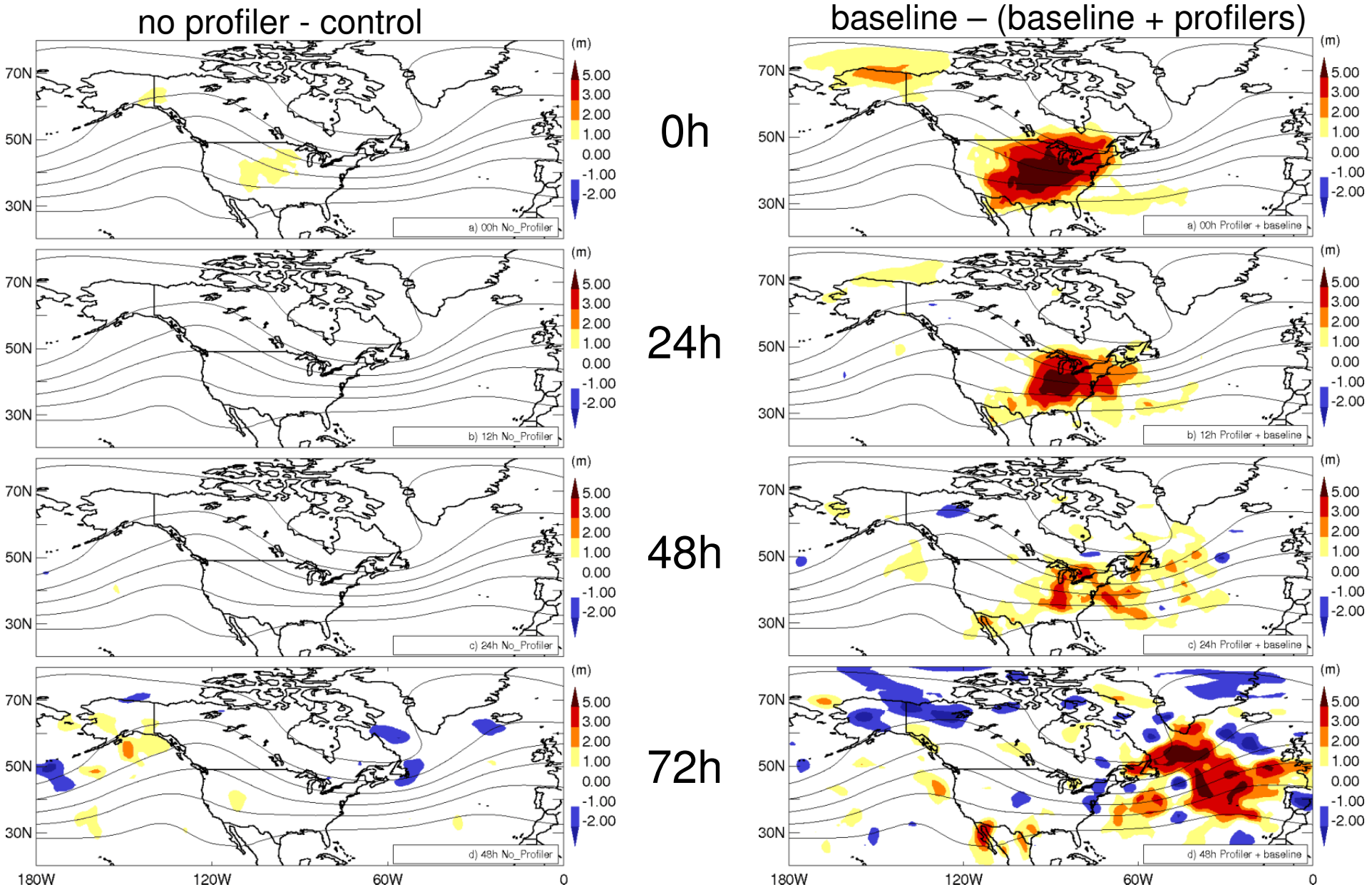
control: All observations operationally assimilated during January and February 2007

baseline: As the control but without the radiosonde and aircraft data over North America



Impact of NOAA wind profiler network on Z500 forecasts

(experiments NO_PROFILER (4D-Var/100 km)



Conclusions (1)

- Summary of the impact results over North America for January and February 2007:

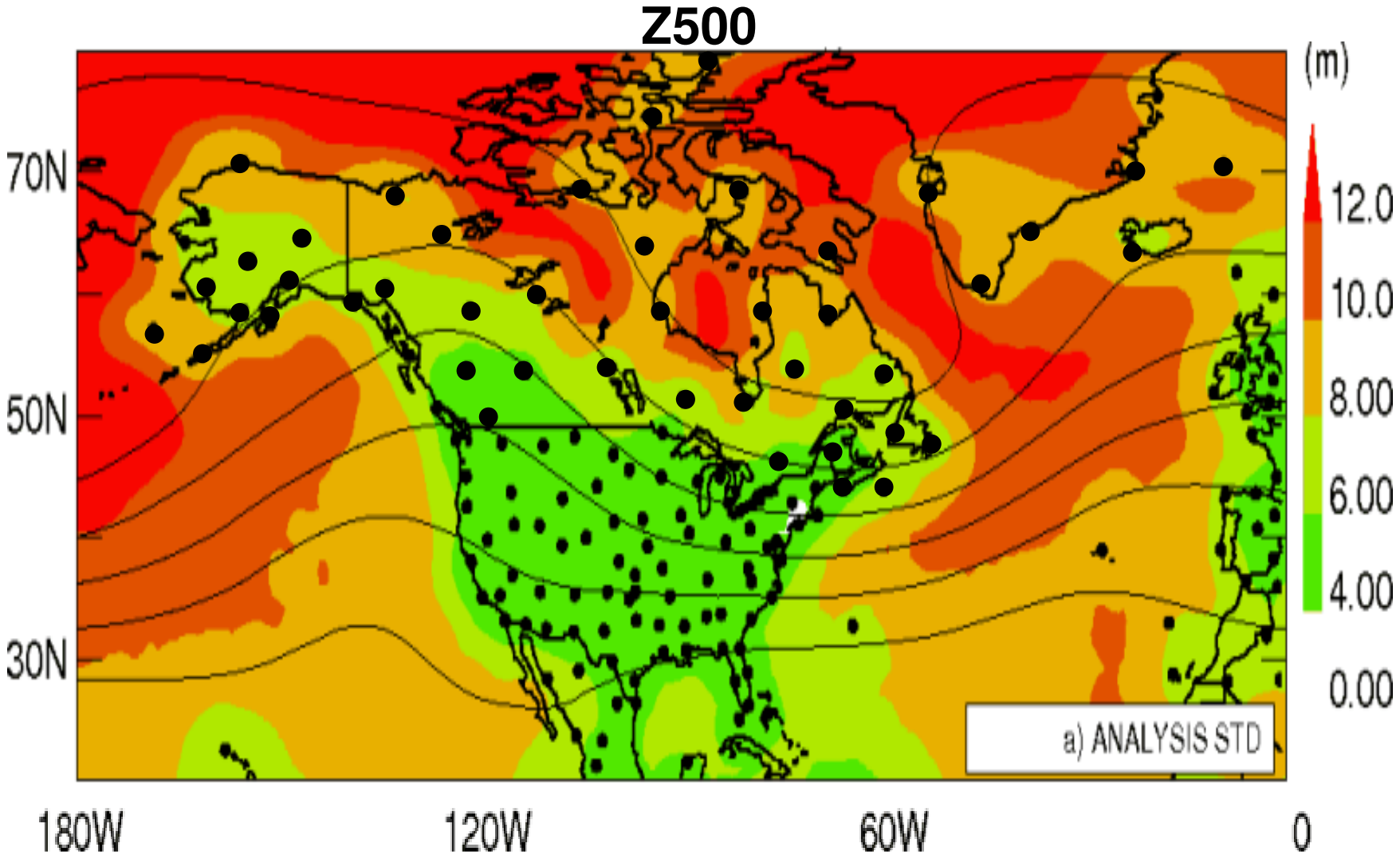
  - ✓ Over the eastern part of the North American continent, the radiosonde and aircraft data are still the main contributors to the forecast skill at short forecast ranges, but beyond 48h the impact of satellite data available over the North Pacific Ocean may be greater depending on the weather regime.

  - ✓ The primary source of forecast improvements over the western North America is provided by the satellite data over the North Pacific Ocean, even at short forecast ranges.

  - ✓ The quality of the forecast over the Canadian Arctic heavily relies on the radiosonde network, even though surface stations and MODIS winds are assimilated.

Analysis error estimation from the EnKF system

(January and February 2007)



Conclusions (2)

- ✓ The impact of the radiosonde network over northern Canada is more important in the 3D-Var context. Moreover, this impact is further enhanced when radiosonde data are omitted over the globe. Therefore, 4D-Var seems superior to 3D-Var to exploit the fewer observations available over northern Canada and is less sensitive to the removal of data outside that region.

- ✓ Overall, the impact results are less sensitive to the change of resolution of the forecast model than to the change of data assimilation scheme for short forecast ranges.

Conclusions (3)

- ✓ The weather regime that prevails during the period under investigation (i.e. January and February 2007) had a noticeable effect, especially on the propagation of the impact from the satellite data over the North Pacific Ocean at longer forecast ranges.

- ✓ As indicated by the variability of the results from the various sensitivity tests, the forecast impact over a given region may change by several percent up to 30% depending on the analysis scheme, the forecast resolution, or the weather regime that prevails during the period investigated.